Final Hydraulics Report

Susquehanna River
Susquehanna County, Pennsylvania

Federal Emergency Management Agency, Region III

Philadelphia, PA

FEMA-1649-DR-PA

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SECTION ONE INTRODUCTION

The study under this task order was conducted for the Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop new flood hazard information in the wake of record flooding caused by rainfall that occurred between June 23 and July 10, 2006, in many areas of the Susquehanna River Basin. Severe concentrated rains caused water levels in rivers and creeks to rise quickly, resulting in flooding of the Delaware, Mohawk, and Susquehanna River basins. The hydraulic analysis for this study resulted in new technical information that will support mitigation and recovery efforts through the production of updated hydrologic and hydraulic models and flood hazard area work maps that can also be used to update Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) for the State of Pennsylvania. The funding for the study was provided by FEMA under the Hazard Mitigation and Technical Assistance Contract Number HSFEHQ-06-D-0162, Task Order HSFEHQ-07-J-0034.

This report describes efforts to quantify the flood hazard risk for the Susquehanna River basin in the Great Bend area of Pennsylvania. The downstream study reach starts at the New York/Pennsylvania State boundary, and the hydraulic analysis covers the Susquehanna River reach that loops through Pennsylvania ending at a point where the Susquehanna River again crosses the New York/Pennsylvania State boundary, approximately 15.6 miles upstream (Figure 3-1). The U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS), Version 3.1.3, was used to perform the hydraulic analysis. HEC GeoRAS Version 4.1 for ArcGIS 9 was used as a pre-processor for inputs to the hydraulic model and a post-processor for delineation of the floodplains.

The hydraulic analysis reflects peak flow discharges summarized in the URS *Hydrology Report Susquehanna River Basin – Study, Susquehanna County*, dated October 2007. Peak flow discharges for the Susquehanna River were calculated at U. S. Geological Survey (USGS) stream gage locations and were computed at other points of interest using gage transfer coefficient equations. A log-Pearson type III analysis using the USGS PeakFQ software was conducted at USGS stream gages for the Susquehanna River at Windsor (gage 01502731) and Conklin (gage 01503000) located in Broome County, NY.

SECTION TWO EXISTING HYDRAULIC ANALYSES AND TOPOGRAPHIC DATA

Within the current study's reach in Susquehanna County, the Susquehanna River was studied in detail for the FIS for the Borough of Great Bend, dated April 1980; the Township of Great Bend, dated July 2, 1980; the Borough of Hallstead, dated March 1980; the Township of Harmony, dated July 16, 1980; the Borough of Lanesboro, dated April 1980; the Borough of Oakland and the Township of Oakland, dated April 1980; and the Borough of Susquehanna Depot, dated April 1980. Analyses of the hydraulic characteristics of the flooding source were carried out to provide estimates of the elevations at selected recurrence intervals along the flooding source. Water surface elevations of floods of these intervals were computed through use of the USACE HEC-2 step-backwater computer program.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Borough of Great Bend, Susquehanna County, were prepared by Justin and Courtney Division of O'Brien and Gere Engineers, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses were obtained from aerial photographs. The below-water sections were obtained by field measurements. The channel roughness value (Manning's "n") used for the river was 0.025, and the overbank roughness value was 0.120 for all floods. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Township of Great Bend, Susquehanna County, were prepared by Justin and Courtney, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses of this part of the Susquehanna River, Salt Lick Creek, DuBois Creek, and Trowbridge Creek were obtained from aerial photographs taken in December 1977. The below-water sections were obtained by field measurements. The channel roughness value for the river was 0.025. For the creeks, the channel roughness values ranged from 0.032 to 0.045, and the overbank roughness values ranged from 0.085 to 0.120 for all floods. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Borough of Hallstead, Susquehanna County, were prepared by Justin and Courtney Division of O'Brien and Gere Engineers, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses of the Susquehanna River, DuBois Creek, and Salt Lick Creek were obtained from aerial photographs. The below-water sections were obtained by field measurements. The channel roughness factor used for the river was 0.025. For the creeks, the channel roughness values ranged from 0.03 to 0.04, and the overbank roughness values ranged from 0.085 to 0.12 for all floods. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Township of Harmony, Susquehanna County, were prepared by Justin and Courtney, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses of the Susquehanna River and Starrucca Creek were obtained from aerial photographs. The below-water sections were obtained by field measurements. The channel roughness value for the river was 0.025. For the creek, the channel roughness values ranged from 0.03 to 0.045, and the overbank roughness values ranged from 0.090 to 0.120 for all floods. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Borough of Lanesboro, Susquehanna County, were prepared by Justin and Courtney, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses of the Susquehanna River and Starrucca Creek were obtained from aerial photographs. The below-water sections were obtained by field measurements. The channel roughness value for the river was 0.025. The channel roughness values for the creek ranged from 0.03 to 0.045, and the overbank roughness values ranged from 0.09 to 0.12 for all floods. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Borough of Oakland, Susquehanna County, were prepared by Justin and Courtney, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses of the Susquehanna River were obtained from aerial photographs. The below-water sections were obtained by field measurements. The channel roughness value for the river was 0.025, and the overbank roughness value was 0.120. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Township of Oakland, Susquehanna County, were prepared by Justin and Courtney, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses of the Susquehanna River were obtained from aerial photographs. The below-water sections were obtained by field measurements. The channel roughness value for the river was 0.025, and the overbank roughness value was 0.120. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

The hydrologic and hydraulic analyses that were used to create data and results for the effective FIS for the Borough of Susquehanna Depot, Susquehanna County, were prepared by Justin and Courtney, Inc., for the Federal Insurance Administration, under Contract No. H-4555. This study was completed in July 1979. Cross-sections for the backwater analyses of the Susquehanna River were obtained from aerial photographs taken in December 1977. The below-water sections were obtained by field measurements. A digital, rectified copy of the work map showing the cross-section location and orientation, streamline, floodplain, and floodway boundaries used for the FIS was available for comparison purposes.

SECTION THREE FLOODPLAIN DESCRIPTION

The Susquehanna River is located within Susquehanna County in Pennsylvania and flows in a westerly direction. The restudied reach in Susquehanna County, PA, extends approximately 15.6 miles from the New York/Pennsylvania State border to the Pennsylvania/New York border in a reach know as the Great Bend of the Susquehanna River. Major tributaries in this part of the Susquehanna River include Canawacta Creek, Drinker Creek, Starrucca Creek, Mitchell Creek, Salt Lick Creek, Hallstead Creek, DuBois Creek, and Trowbridge Creek. Four bridges and an inline structure are located within the study area; all of these structures are included in the hydraulic analysis. The study area and location of the cross-sections for the Susquehanna River are shown in Figure 3-1.

The stream is characterized by confined and well-defined floodplains. Development within the floodplain of the Susquehanna River in Pennsylvania consists of residential, commercial, and industrial areas. There are a few agriculture fields adjacent to the floodplain.

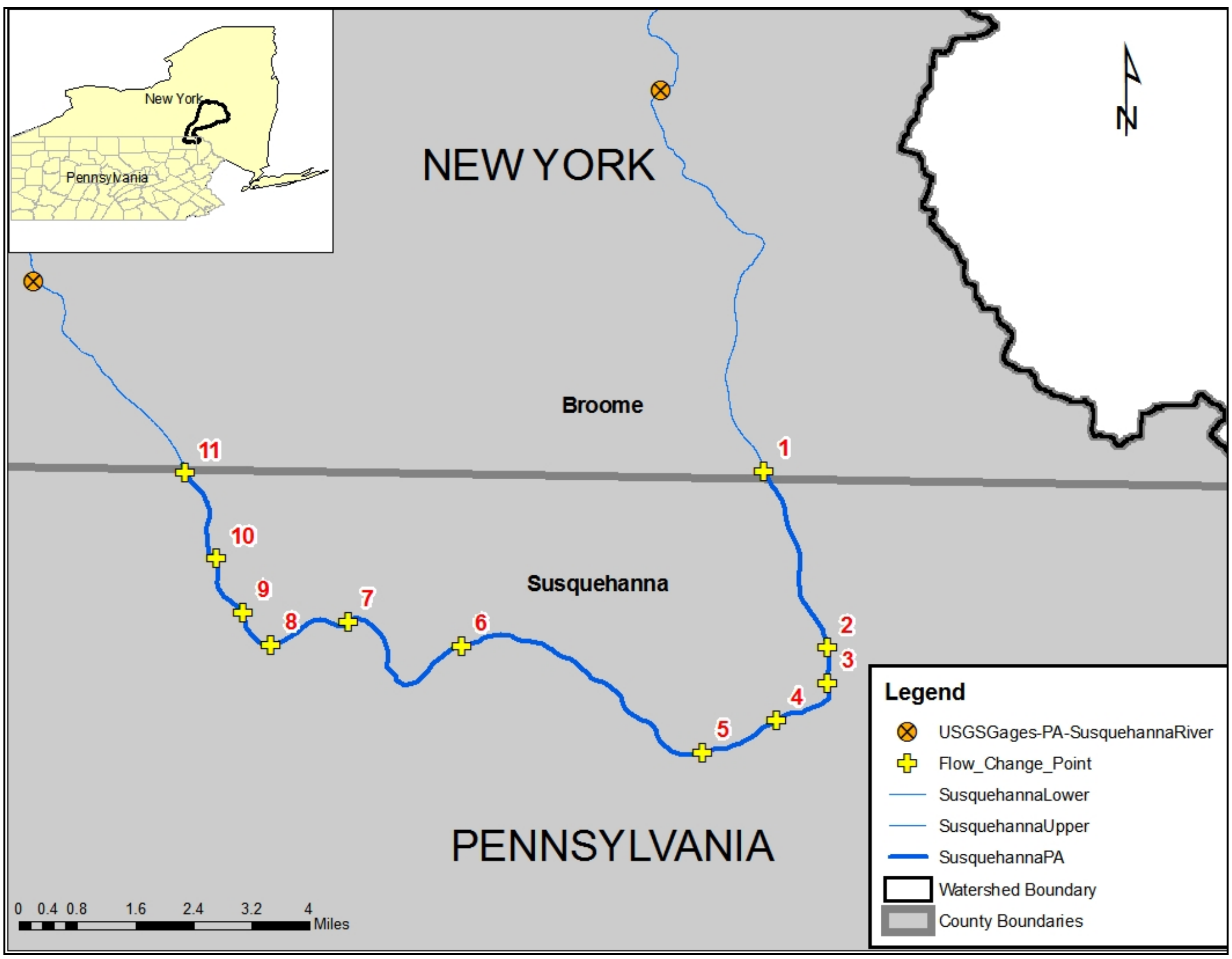


Figure 3-1: Study Area for the Susquehanna River in Pennsylvania and Cross-Section Locations.

SECTION FOUR GROUND SURFACE REPRESENTATION

The data collected from two sources: Light Detection and Ranging (LiDAR) and field survey, were combined to create an accurate representation of the ground surface within the floodplain area for hydraulic analysis and floodplain delineation purposes. These sources are detailed in the following sections.

4.1 LIGHT DETECTION AND RANGING (LIDAR)

This LiDAR project (USGS Contract No: 07CRCN004) covered approximately 2,714 square miles of floodplain area for the Susquehanna River, Delaware River, and Mohawk River basins in the States of New York and Pennsylvania. The LiDAR data were collected in spring 2007 and processed by Terrapoint USA, a subcontractor to Dewberry. Dewberry performed the quality assurance/quality control (QA/QC) review to ensure the data met the desired specifications and to verify the usability of the data. Dewberry prepared a report for the USGS entitled *LiDAR QA/QC - Quantitative and Qualitative Assessment Report – NY FEMA Flood Mitigation, LiDAR,* dated September 14, 2007. Data for the portion of Pennsylvania studied under this Task Order was collected with the New York data.

The LiDAR product is a mass point dataset with an average point spacing of 1 meter (m). The data is tiled and stored in .LAS format. LiDAR returns are classified in two classes: ground and non-ground. The data meets the accuracy required for this project (2-foot [ft] contours according to Appendix A of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, dated April 2003). Compared with the Fundamental Vertical Accuracy specification of 36.3 centimeters (cm), these data tested at 14.2 cm Fundamental Vertical Accuracy at a 95-percent confidence level in open terrain using the Root Mean Square Error (RMSE) method x 1.96 on 160 and 79 survey points, respectively. Based on quantitative and qualitative assessments, the data easily met the desired accuracy for floodplain mapping.

4.2 TERRAIN DEVELOPMENT

The bare earth LiDAR data were used to develop a digital terrain model in the form of a Triangulated Irregular Network (TIN). The TIN surface was generated as the source of ground elevations for the hydraulic model preparation and mapping work using ESRI's ArcGIS 9 software.

4.3 FIELD SURVEY DATA

Four bridges, an inline structure, and a total of 33 cross-sections (upstream and downstream, most sections are the same sections used in the Hazard Mitigation Technical Assistance Program [HMTAP] Task Order HSFEHQ-06-J-0065 study) were surveyed in accordance with Appendix N of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners,* dated May 2005. Detailed information from the bridge and inline structure survey is presented in Appendix A. There is no flood protection structures located within this reach of river.

SECTION FIVE HYDRAULIC MODEL DEVELOPMENT

5.1 MODEL AND COMPUTER TOOLS USED

HEC-RAS Version 3.1.3 was used for the hydraulic analysis. GeoRAS Version 4.1 for ArcGIS 9 was used to generate the required geometry file from the developed TIN. Check-RAS Version 1.4 was used to verify the model. It should be noted that a NAD_1983_UTM_Zone_18N projection in SI units was used in ArcGIS, which has been converted into U.S. Customary units in HEC-RAS model for analysis and submission.

5.2 MAIN STREAM AND FLOW PATHS

The main channel was delineated using field survey data, and aerial photographs for Susquehanna County were adopted from the Web site of Pennsylvania Spatial Data Access (PASDA, http://www.pasda.psu.edu). The streamline was digitized by snapping vertices to the lowest survey point at each surveyed cross-section. In between surveyed cross-sections, the streamline was interpreted from the aerial photography and verified using the digital terrain model from the LiDAR data.

5.3 CROSS-SECTION GENERATION

A total of 95 hydraulic cross-sections were cut from the digital terrain model for the HEC-RAS hydraulic model. Of those cross-sections, 33 were based on field survey data obtained between July and December 2007. In general, survey data were used to develop the channel portion of the cross-section geometry, while the TIN was the source of overbank topography. A Geographic Information System (GIS)-based program was used to integrate the survey data into cross-section station/elevation information for HEC-RAS. Locations along the cross-sections where the vertices from the survey data and vertices from the TIN were adjacent further validated the accuracy of the LiDAR data. The remaining 62 cross-sections were obtained by interpolation using adjacent surveyed cross-sections. Overbank portions of the interpolated cross-sections are based on LiDAR data.

5.4 MANNING'S ROUGHNESS COEFFICIENT (N) CALCULATIONS

Manning's coefficient values were determined for each cross-section using the USGS (1989) procedure outlined in the *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains*. The ground-level photographs taken during the field survey in conjunction with the aerial images were used to estimate Manning's coefficients for the channel portion of the cross-section. In the overbanks areas, land-use classification data was developed from the aerial imagery by digitizing polygons of different land-use types and attributing a Manning's n value to each polygon in accordance with the USGS procedure. For the main channel, the Manning's n values ranged from 0.038 to 0.04, while for the overbanks areas, the values ranged from 0.016 for asphalt areas to 0.12 for forested areas. Appendix B depicts the Manning's coefficient values used in the hydraulic model.

5.5 ROADWAY CROSSINGS

Four bridges cross the Susquehanna River and were included in the HEC-RAS model. Appendix A lists the modeled bridges by their stationing and names from both the HEC-RAS model and the field survey. Appendix C shows the photographs of these structures taken during the field survey. The photographs are labeled with the stationing and node name.

5.6 INLINE STRUCTURES

An inline structure crosses the Susquehanna River within the study area and was included in the HEC-RAS model. Appendix A lists the modeled inline structure by its stationing and name from both the HEC-RAS model and the field survey. Appendix C shows a photograph of this structure taken during the field survey.

5.7 COEFFICIENTS OF CONTRACTION AND EXPANSION

Typical contraction and expansion coefficients of 0.1 and 0.3, respectively, were used for all natural valley cross-sections. For bridges, typical contraction and expansion coefficients of 0.3 and 0.5, respectively, were used at one downstream and two upstream cross-sections. These three cross-sections are referred to as cross-sections number 2, 3, and 4 in the *HEC-RAS Hydraulic Reference Manual* (USACE, 2002).

5.8 DISCHARGES

As described above, discharges for the Susquehanna River were developed using a combination of stream gage analysis and transfer equations. PeakFQ (Version 5.0 Beta 8; Flynn et al., 2006) was used for the frequency analysis of the gage data. The discharges for the 10-, 50- 100-, and 500-year frequency discharge were plotted versus drainage area for the two USGS gages to establish the discharge for areas between the two gages. Details on the methodology used to calculate discharges along the Susquehanna River are included in the companion URS report *Hydrology Report Susquehanna River Basin – Study, Susquehanna County*, dated October 2007.

Appendix D lists the cross-section stationing and the 10-, 50-, 100-, and 500-year and 2006 flood event discharges at each location. The 2006 flood event discharges are quite comparable to the newly developed 1-percent-annual-chance discharges.

5.9 STARTING WATER-SURFACE ELEVATION

The downstream water surface elevation, taken from the modeled water surface elevation near the New York/Pennsylvania border for the 10-, 50-, 100-, and 500-year and 2006 flood event, was used as the boundary condition of this model.

SECTION SIX MODEL CALIBRATION USING THE JUNE 2006 FLOOD EVENT

The hydraulic model was calibrated using high water marks (HWMs) measured by the USGS after the extreme flood event of 2006. Four HWMs were recorded from the houses that sustained flood damage, located near the New York/Pennsylvania border at Great Bend. However, only two of the HWMs were suitable for calibration purposes, since the other two HWMs were collected in a backwater area and not along the main stem of Susquehanna River.

Table 6-1 presents the results of running the June 2006 discharges through the new model against the gage data and HWMs. In accordance with the calibration criteria, the HEC-RAS model calibrated within +/- 0.5 foot of the observed HWMs.

Table 6-1: High Water Marks: Susquehanna River

Site name or USGS gaging station name	Modeled water surface elevation June 2006 NAVD 88* (ft)	Peak flood elevation June 2006 NAVD 88 (ft)	Difference in high water mark (observed-model in ft)	Effective FIS water-surface elevations, referenced to NAVD 88 (ft)			
				10-year flood	50-year flood	100-year flood	500-year flood
Site # 1	872.34	872.36	-0.02	867.19	870.20	871.39	874.06
Site # 4	873.62	874.04	-0.42	868.86	871.65	872.76	875.22

* NAVD 88 = North American Vertical Datum of 1988

SECTION SEVEN RESULTS

7.1 FLOODPLAIN MAPPING

Figure 7-1 presents the 100-year floodplain mapping generated for the part of the Susquehanna River in Pennsylvania. Work maps at a 1:6000 scale (1 inch =500 feet) are also included with this submittal.

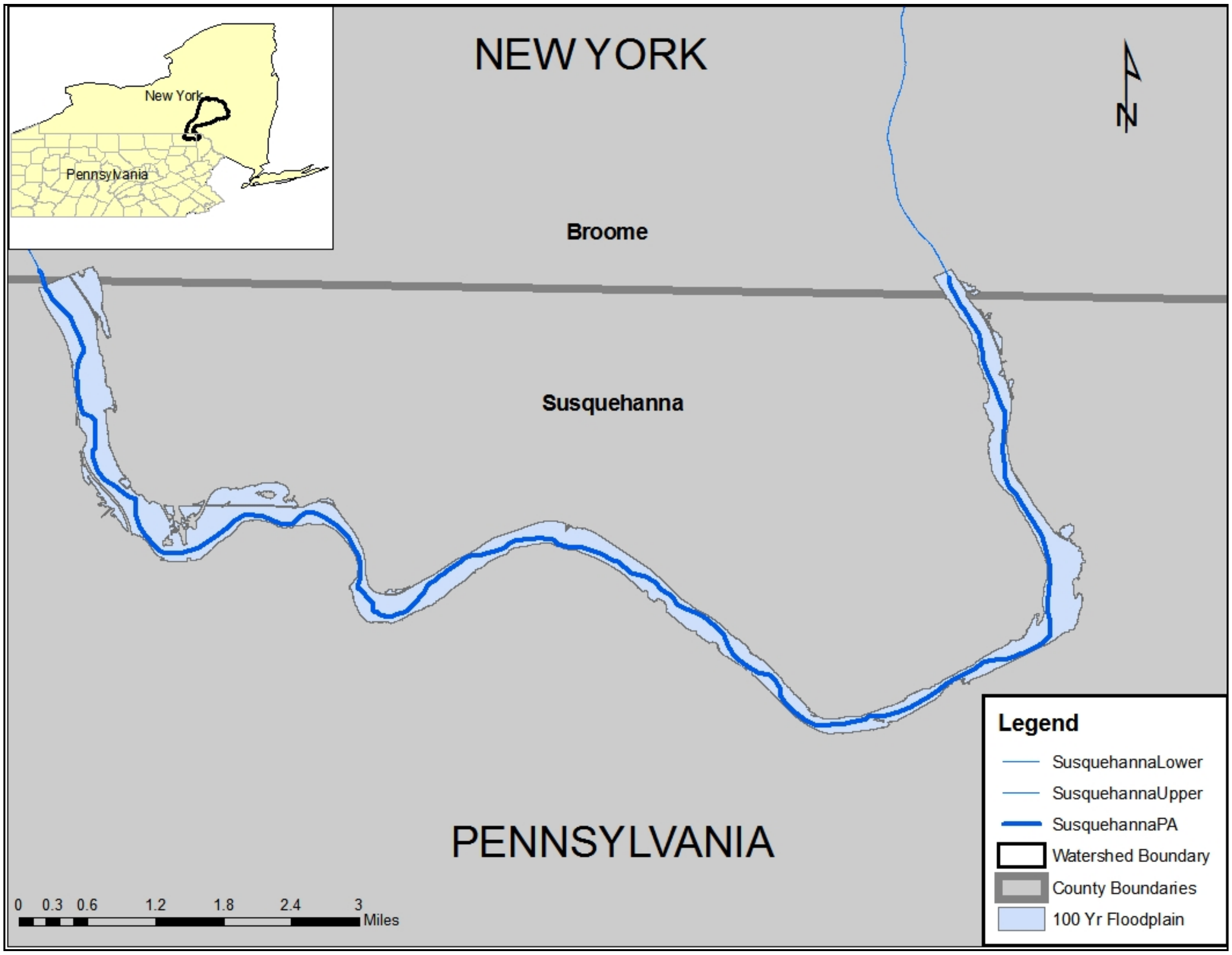


Figure 7-1: Susquehanna River Pennsylvania Portion, 100-Year Floodplain

7.2 PROFILE

Appendix E includes the profiles generated for the entire stream using RASPLOT Version 2.5.

7.3 FLOODWAY

The floodway boundary was adjusted using the equal conveyance reduction criterion option (Method 4) available in the HEC-RAS model until the surcharge was less than the allowable limit of 1.00 foot for each cross-section. The HEC-RAS Floodway Data Table is presented in Appendix F.

The revised floodway compares generally well with the floodway of the effective FISs. Floodway widths computed in this study increase and decrease in relation to the effective FIS. Work maps at a 1:6000 (1 inch =500 feet) scale showing floodway delineations are also included with this submittal.

Appendix A

Bridges and Inline Structure Details

Bridge Details

S.No	Station/Node Name	Name of the Bridge	Width (ft)	Structure Opening (ft^2)	Upstream cross-section and distance (ft)		Downstream cross-section and distance (ft)		US/DS Min Top of Road (ft)	US/DS Max Low Chord (ft)
1	18830.19/11.50	Vet. Memorial Bridge	49.74	86274.98	Node Name 11.52	61.61	Node Name 11.48	73.88	920.83	930.92
									921.98	930.92
2	17508.12/BR10.80	RR Bridge	34.19	63126.00	Node Name 10.83	160.10	Node Name 10.77	143.63	908.43	909.86
									908.43	909.86
3	5085.119/3.17BR	RT81 Bridge	121.06	58008.94	Node Name 3.17US	37.40	Node Name 3.14	38.42	874.84	886.42
									874.61	886.42
4	47.17.031/BR2.94	RT 11 Bridge	53.48	39466.02	Node Name 2.94US	31.56	Node Name 2.93	38.78	865.98	879.54
									864.74	879.39

Inline Structure Details

S.No	Station/Node Name	Width (ft)	Upstream cross-section and distance (ft)		Downstream cross-section and distance (ft)		Spillway Elevation (ft)	Spillway Shape (ft)
1	17852.95/11.00	1.97	10.98	89.14	11.02	101.31	889.009	broad-crested

Appendix B

N-Value Computation Summary

Susquehanna County, PA

Table of Manning's n Values

ID	Description	n value
CHAN	**Main Channel (Open)**	
	Refer to HEC-RAS Hydraulics Reference Manual Table 3.1 for n values	0.037 to 0.04
	Main Channel (Conduit)	
	Refer to HEC-RAS Hydraulics Reference Manual Table 6.1 for n values	
	Floodplains (overbank areas)	
	Open Space	
OS1	Asphalt	0.016
OS2	Short Grass (lawn)	0.03
OS3	High Grass	0.035
	Agriculture Area	
A1	No Crop	0.03
A2	Mature Row Crop	0.035
A3	Mature Field Crop	0.04
	Brush	
B1	Scattered Brush (Heavy Weeds)	0.05
B2	Light Brush and Trees	0.06 to 0.08
B3	Medium Dense Brush	0.1
	Forest	
F1	Heavy stand of timber (closed canopy), few downed trees, little undergrowth, flood stage below branches	0.1
F2	Heavy stand of timber (partial canopy), few downed trees, undergrowth, flood stage into branches	0.12

CHANNEL ROUGHNESS, (MANNING'S N)

Stream: Susquehanna River			**Project: Susquehanna,**		
Designed by: Syeed Ullah	**Date: 6//2007**	**Checked by:**	**Date:**		

	Columns	*nb*				*n1*				*n2*			*n3*				*n4*				*n5*			*n*
Classification	**Description of Reach, Station, or Cross-Section**	**Basin n**				**Surface Irregularity**				**Variations in Size and Shape of Cross-Section**			**Obstructions**				**Vegetation**				**Meandering**			**Total "n"** *(nb+n1+n2+n3+n4)*n5*
		0.020	0.025	0.024	0.028	0.000	0.005	0.010	0.020	0.000	0.005	0.010 0.015	0.000 0.004	0.010 0.015	0.020 0.030	0.040 0.060	0.005 0.010	0.010 0.025	0.025 0.050	0.050 0.100	1.000	1.150	1.300	
		Earth	Rock	Fine Gravel	Coarse Gravel	Smooth	Minor	Moderate	Severe	Straight Gradual	Occasional Shifting	Frequent Shifting	Negligible	Minor	Appreciable	Severe	Low	Medium	High	Very High	Minor 1.0 to 1.22	Appreciable 1.2 to 1.52	Severe 1.52+	
1	from d/s most XS to XS 16083.02			0.024			0.005			0.000			0.004				0.005				1.000			0.038
2	from d/s to XS 16319.22 to u/s most XS		0.025				0.005			0.000			0.004				0.006				1.000			0.040

XS 0.14: From Right Bank Looking Downstream

XS 0.14: From Left Bank Looking Upstream

XS 0.62: From Channel Looking Downstream

XS 0.62: From Channel Looking Upstream

XS 1.32: From Channel Looking Downstream

XS 1.32: From Channel Looking Upstream

XS 1.97: From Channel Looking Downstream

XS 1.97: From Channel Looking Upstream

XS 2.40: From Channel Looking Downstream

XS 2.40: From Channel Looking Upstream

XS 2.93: From Channel Looking Downstream

XS 2.93: From Channel Looking Upstream

XS 2.95: From Left Bank Looking Downstream

XS 2.95: From Channel Looking Upstream

XS 3.14: From Channel Looking Downstream

XS 3.14: From Channel Looking Upstream

XS 3.20: From Channel Looking Downstream

XS 3.20: From Channel Looking Upstream

XS 3.72: From Right Bank Looking Downstream

XS 3.72: From Right Bank Looking Upstream

XS 4.65: From Channel Looking Downstream

XS 4.65: From Channel Looking Upstream

XS 5.55: From Channel Looking Downstream

XS 5.55: From Left Bank Looking Upstream

XS 6.49: From Left Bank Looking Downstream

XS 6.49: From Left Bank Looking Upstream

XS 7.38: From Left Bank Looking Downstream

XS 7.38: From Left Bank Looking Upstream

XS 8.52: From Left Bank Looking Downstream

XS 8.52: From Right Bank Looking Upstream

XS 9.06: From Right Bank Looking Downstream

XS 9.06: From Right Bank Looking Upstream

XS 9.79: From Right Bank Looking Downstream

XS 9.79: From Right Bank Looking Upstream

XS 10.77: From Left Bank Looking Downstream

XS 10.77: From Left Bank Looking Upstream

XS 10.83: From Right Bank Looking Downstream

XS 10.83: From Left Bank Looking Upstream

XS 10.98: From Channel Looking Downstream

XS 10.98: From Channel Looking Upstream


XS 11.29: From Left Bank Looking Downstream


XS 11.29: From Left Bank Looking Upstream


XS 11.48: From Channel Looking Downstream


XS 11.48: From Channel Looking Upstream

XS 11.52: From Channel Looking Downstream

XS 11.52: From Channel Looking Upstream

XS 12.18: From Channel Looking Upstream

XS 12.18: From Channel Looking Upstream

XS 13.12: From Channel Looking Downstream

XS 13.12: From Channel Looking Downstream

XS 13.89: From Channel Looking Downstream

XS 13.89: From Channel Looking Upstream

XS 14.52: From Left Bank Looking Downstream

XS 14.52: From Left Bank Looking Downstream

XS 15.18: From Left Bank Looking Downstream

XS 15.18: From Left Bank Looking Upstream

XS 15.79: From Right Bank Looking Downstream

XS 15.79: From Right Bank Looking Upstream

XS 15.18: From Left Bank Looking Downstream

XS 15.18: From Left Bank Looking Upstream

Appendix C

Selected Photographs

Figure 1. BR 2.94 – Route 11 Bridge

Figure 2. BR 3.17 – Route 81 Bridge

Figure 3. BR 10.80 – Rail Road Bridge

Figure 4. BR 11.50 – Veteran Memorial Bridge

Figure 5. Dam 11.00 – Susquehanna Dam

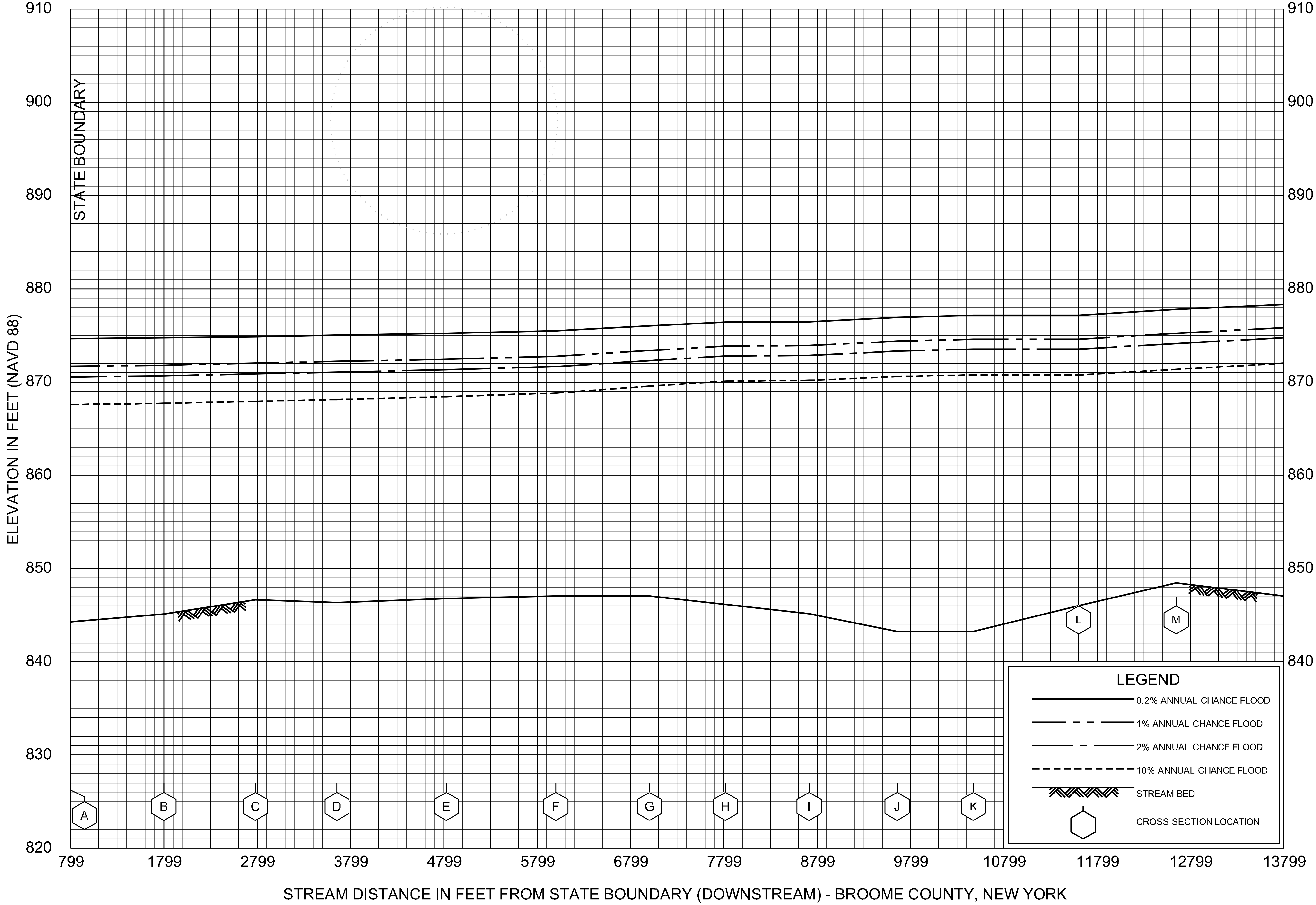
Appendix D

Discharge Flow Change Locations

Table 2.6: Recommended Discharges for Hydraulic Analysis

ID	Description	DA (Sq.Mi)	Q10-Yr (cfs)	Q50-Yr (cfs)	Q100-Yr (cfs)	Q500-Yr (cfs)	Q_2006 (cfs)
1	Upstream Study Limit - NY/PA State Line	1,887	41,626	54,389	59,691	71,674	57,608
2	Effective FIS Location - upstream of Starrucca Creek	1,905	41,911	54,747	60,079	72,142	58,544
3	Upstream of Canawacta Creek	1,981	43,500	56,826	62,399	75,059	62,611
4	Upstream of Drinker Creek	1,995	43,814	57,237	62,859	75,649	63,402
5	Effective FIS Study - downstream of Oakland and Susquehanna Depot & downstream of Inline Structure	2,005	44,031	57,518	63,172	76,064	63,914
6	Upstream of Mitchell Creek	2,022	44,386	57,999	63,723	76,778	64,831
7	Upstream of Unnamed Tributary to Susquehanna River	2,037	44,654	58,371	64,130	77,308	65,681
8	Upstream of Salt Lick Creek	2,043	44,754	58,492	64,270	77,498	66,030
9	Effective FIS Location - Downstream of Hallstead and upstream of DuBois Creek	2,084	45,695	59,747	65,669	79,279	68,268
10	Upstream of Town Bridge Creek	2,097	45,991	60,125	66,087	79,806	69,040
11	Downstream study limit - NY/PA State Line & Effective FIS Location - downstream of Township of Great Bend	2,118	46,364	60,594	66,594	80,427	70,210

Appendix E
Profiles



FLOOD PROFILES

SUSQUEHANNA RIVER

FEDERAL EMERGENCY MANAGEMENT AGENCY

SUSQUEHANNA COUNTY, PA

HSFEHQ-06-D-0162

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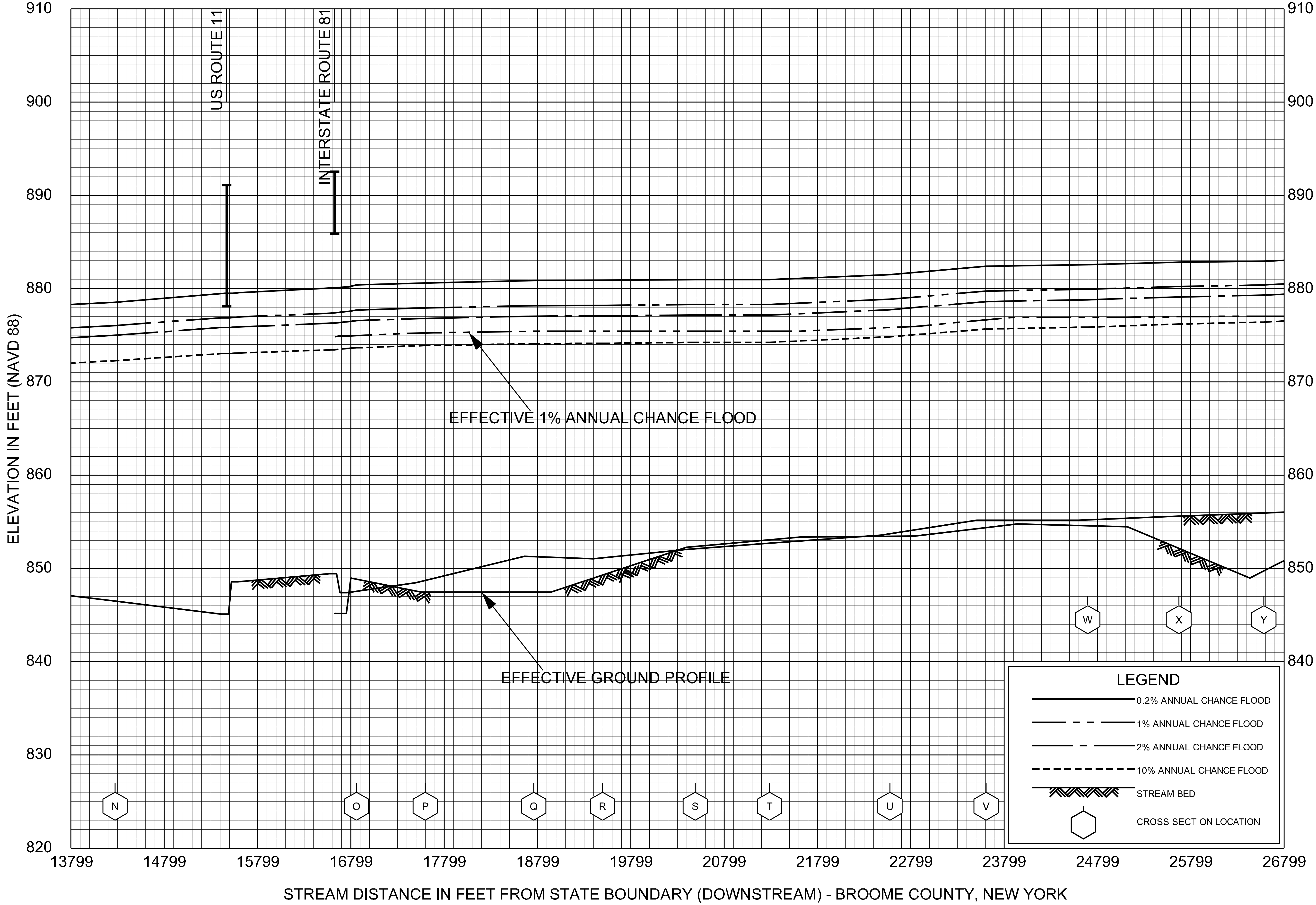

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FEDERAL EMERGENCY MANAGEMENT AGENCY

SUSQUEHANNA COUNTY, PA

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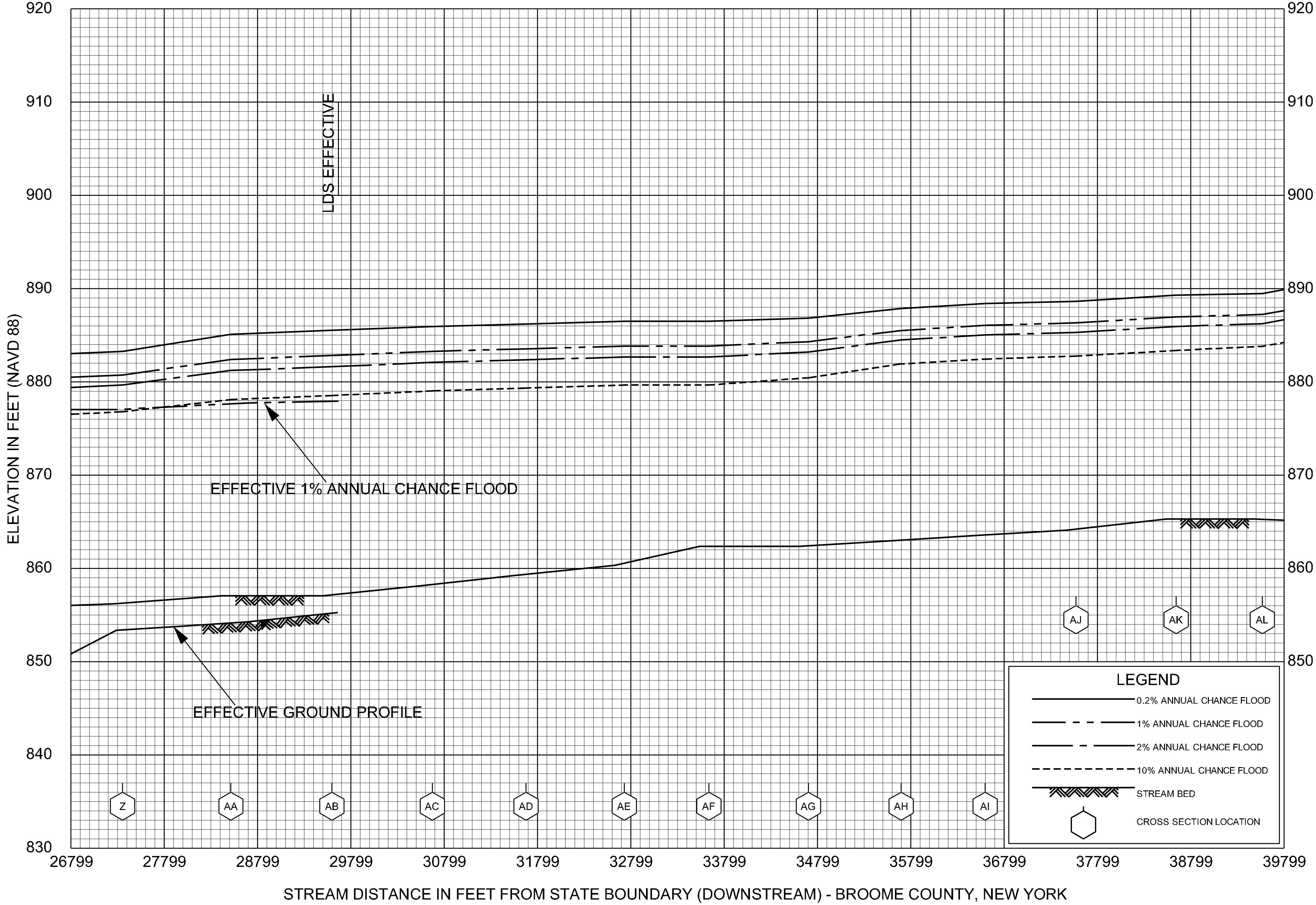

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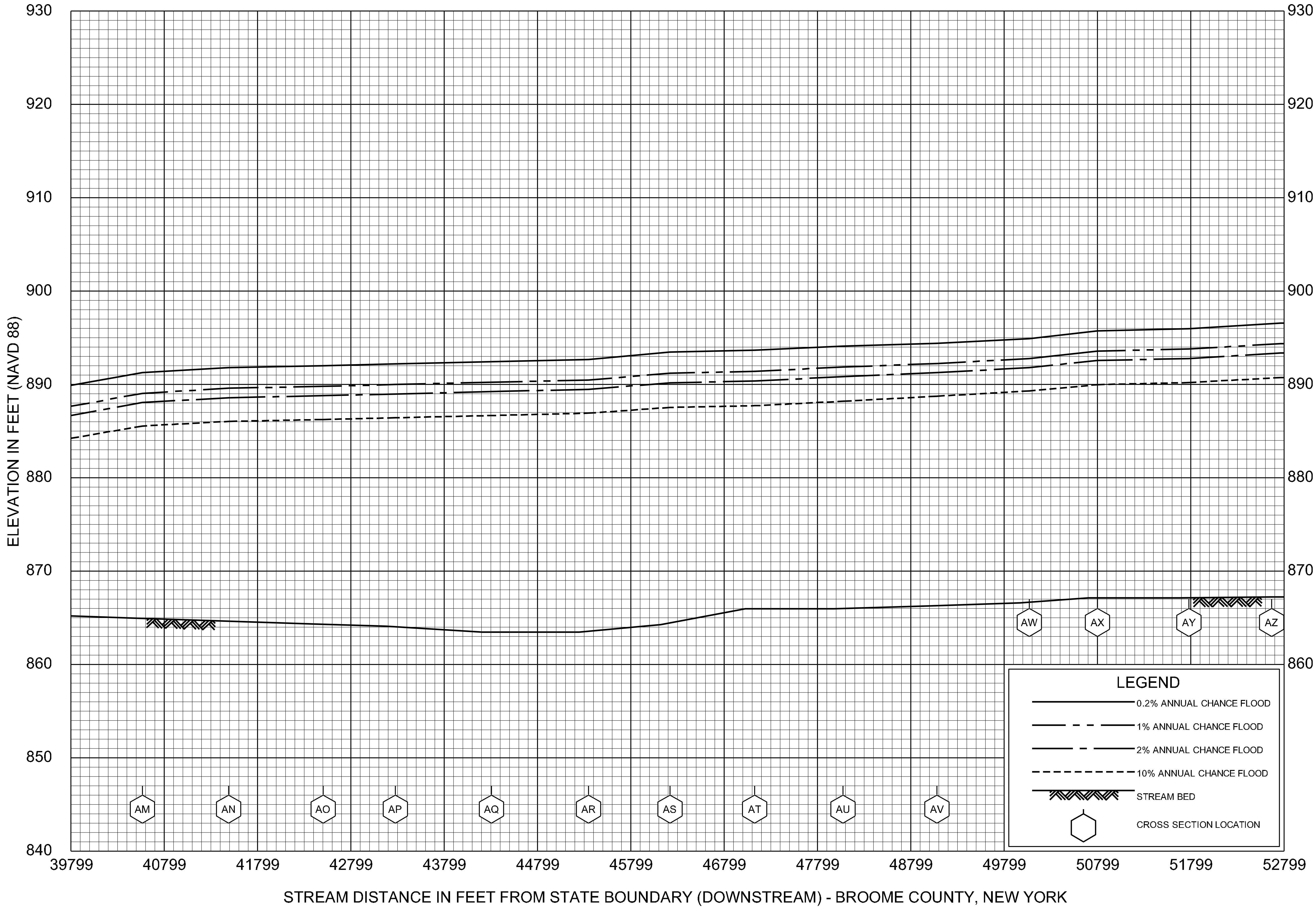

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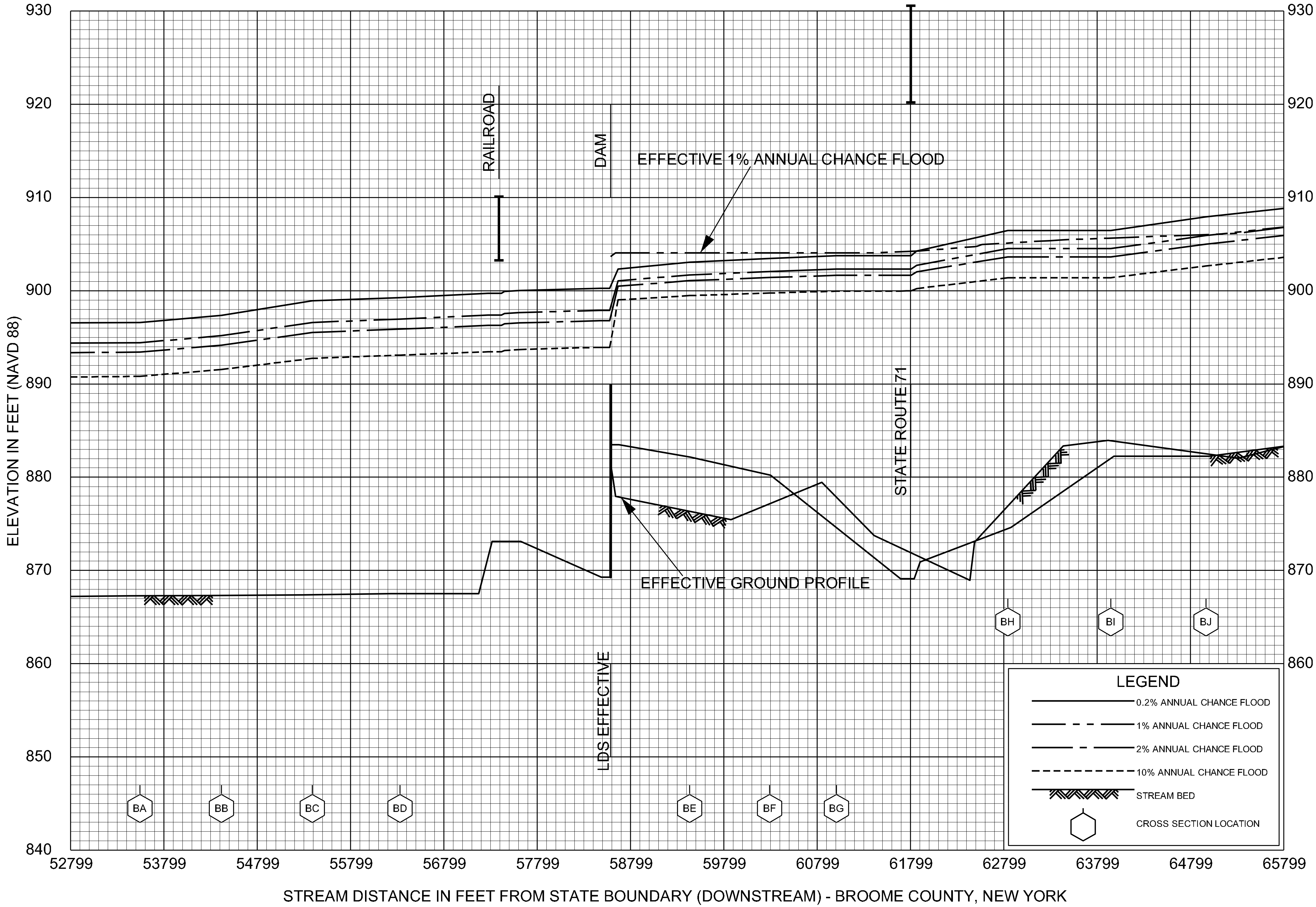

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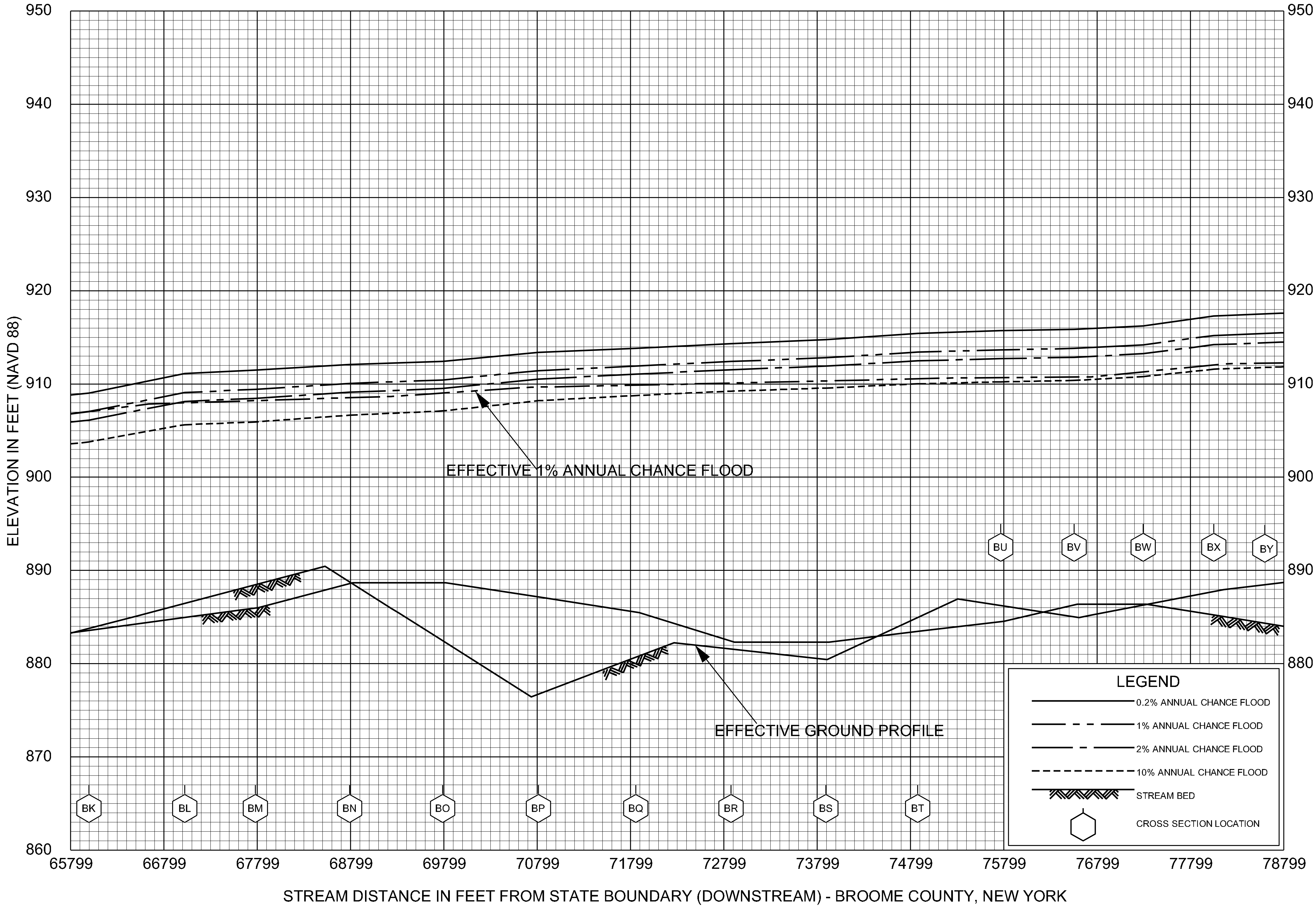

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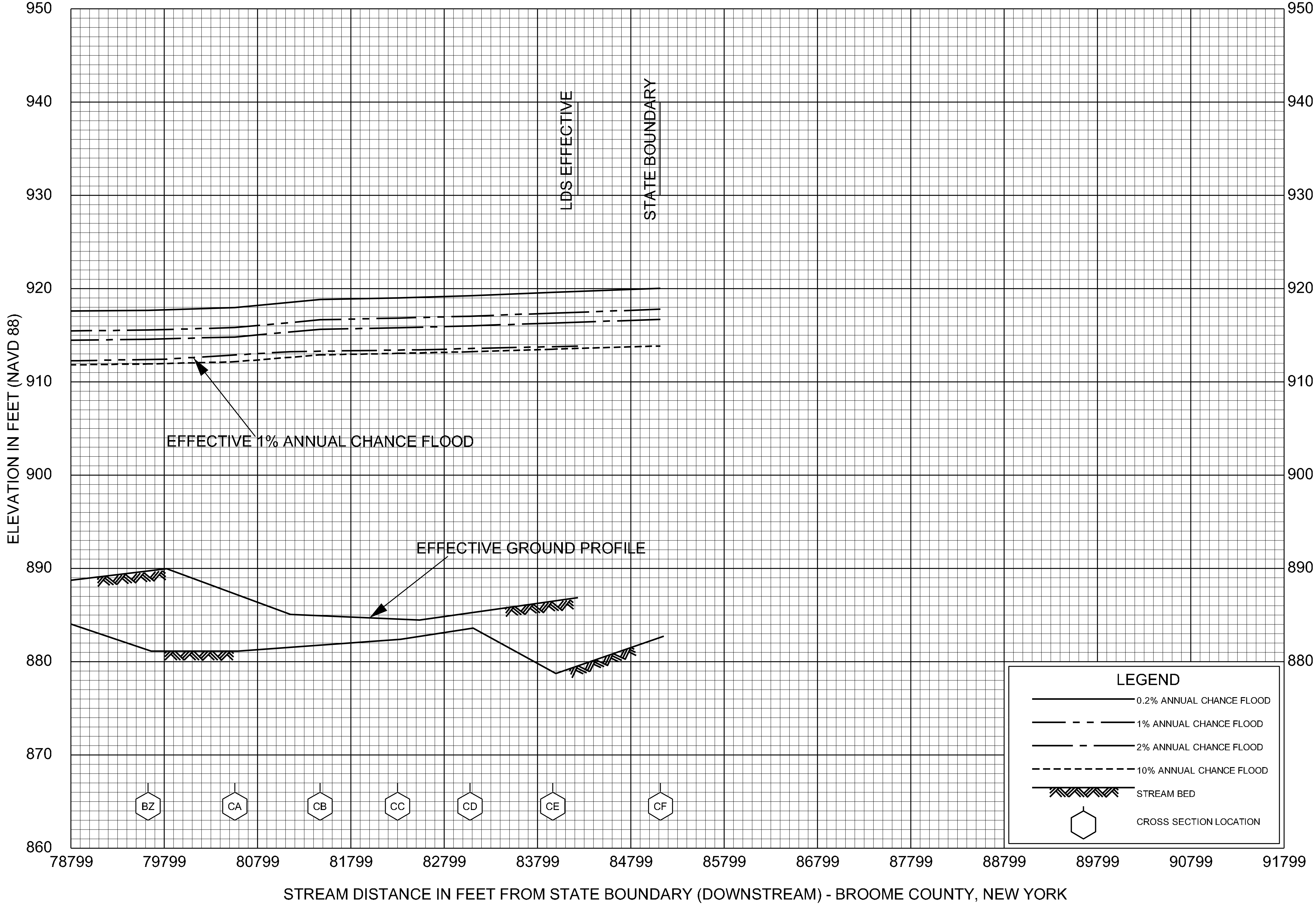

FLOOD PROFILES

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Appendix F

HEC-RAS Floodway Data Table

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
A	799	100 Year	1551	32845	2.69	871.7	871.7	
	799	FW	918	18246	3.65	872.5	871.7	0.8
B	1798	100 Year	1736	34100	2.65	871.8	871.8	
	1798	FW	1115	20021	3.33	872.7	871.8	0.9
C	2777	100 Year	1726	31896	2.65	872.0	872.0	
	2777	FW	1306	22768	2.92	873.0	872.0	1.0
D	3652	100 Year	1625	25724	2.80	872.2	872.2	
	3652	FW	1542	24506	2.72	873.2	872.2	1.0
E	4824	100 Year	1635	21413	3.11	872.4	872.4	
	4824	FW	960	16428	4.05	873.3	872.4	0.9
F	5997	100 Year	1544	17620	3.78	872.8	872.8	
	5997	FW	1143	15723	4.24	873.7	872.8	0.9
G	7001	100 Year	1743	20435	3.26	873.4	873.4	
	7001	FW	1153	17916	3.72	874.3	873.4	0.9
H	7814	100 Year	1328	21442	3.27	873.9	873.9	
	7814	FW	880	17270	3.86	874.8	873.9	0.9
I	8711	100 Year	1166	14166	4.67	873.9	873.9	
	8711	FW	690	12990	5.09	874.8	873.9	0.9
J	9655	100 Year	1325	19774	3.39	874.4	874.4	
	9655	FW	710	15671	4.22	875.3	874.4	0.9
K	10472	100 Year	1295	24291	3.04	874.6	874.6	
	10472	FW	800	18625	3.55	875.5	874.6	0.9

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
L	11600	100 Year	682	15486	5.80	874.5	874.5	
	11600	FW	680	12055	5.48	875.4	874.5	0.9
M	12645	100 Year	1123	17755	4.54	875.2	875.2	
	12645	FW	1020	14408	4.59	876.1	875.2	0.9
N	14271	100 Year	1276	14771	5.36	876.1	876.1	
	14271	FW	1015	12077	5.44	876.8	876.1	0.7
	15409	100 Year	545	20191	5.38	876.9	876.9	
	15409	FW	547	12597	5.21	877.6	876.9	0.7
	15475. BR D	100 Year	513	11877	5.53	876.9	876.9	
	15475. BR D	FW	406	12196	5.38	877.6	876.9	0.7
	15475. BR U	100 Year	521	11324	5.8	876.9	876.9	
	15475. BR U	FW	419	11656	5.63	877.6	876.9	0.7
	15533	100 Year	533	19301	5.65	876.9	876.9	
	15533	FW	533	11998	5.47	877.6	876.9	0.7
	15603	100 Year	541	13436	5.60	877.0	877.0	
	15603	FW	454	11401	5.76	877.7	877.0	0.7
	16585	100 Year	741	13525	5.00	877.4	877.4	
	16585	FW	745	13358	4.81	878.1	877.4	0.7
	16682. BR D	100 Year	655	12382	5.19	877.4	877.4	
	16682. BR D	FW	655	12832	5.01	878.1	877.4	0.7
	16682. BR U	100 Year	637	12573	5.11	877.5	877.5	
	16682. BR U	FW	640	13003	4.94	878.2	877.5	0.7

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
	16781	100 Year	698	19151	4.92	877.6	877.6	
	16781	FW	702	13538	4.75	878.2	877.6	0.6
O	16857	100 Year	1421	22901	3.85	877.7	877.7	
	16857	FW	573	12980	4.95	878.3	877.7	0.6
P	17595	100 Year	1212	22481	3.24	877.9	877.9	
	17595	FW	628	15879	4.05	878.6	877.9	0.7
Q	18759	100 Year	1725	28784	2.36	878.2	878.2	
	18759	FW	799	20356	3.16	878.8	878.2	0.6
R	19495	100 Year	1062	26682	3.35	878.2	878.2	
	19495	FW	832	18155	3.54	878.8	878.2	0.6
S	20490	100 Year	696	22233	4.17	878.3	878.3	
	20490	FW	650	15742	4.08	878.9	878.3	0.6
T	21286	100 Year	777	20518	4.89	878.3	878.3	
	21286	FW	572	11126	5.78	878.8	878.3	0.5
U	22577	100 Year	908	14141	4.93	878.9	878.9	
	22577	FW	655	11187	5.75	879.4	878.9	0.5
V	23606	100 Year	1017	16798	3.82	879.8	879.8	
	23606	FW	750	15939	4.02	880.4	879.8	0.6
W	24696	100 Year	757	13119	4.89	879.9	879.9	
	24696	FW	706	13498	4.75	880.6	879.9	0.7
X	25674	100 Year	554	11464	5.59	880.2	880.2	
	25674	FW	490	11528	5.56	880.9	880.2	0.7

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
Y	26583	100 Year	423	8548	7.5	880.4	880.4	
	26583	FW	390	8645	7.42	881.0	880.4	0.6
Z	27351	100 Year	327	7209	8.9	880.8	880.8	
	27351	FW	318	7363	8.71	881.3	880.8	0.5
AA	28513	100 Year	959	15148	4.23	882.4	882.4	
	28513	FW	690	12911	4.97	882.9	882.4	0.5
AB	29596	100 Year	1471	19402	3.31	882.8	882.8	
	29596	FW	877	14888	4.31	883.3	882.8	0.5
AC	30670	100 Year	1239	19884	3.26	883.3	883.3	
	30670	FW	1085	19283	3.33	883.8	883.3	0.5
AD	31675	100 Year	1135	18216	3.53	883.6	883.6	
	31675	FW	1121	18733	3.42	884.1	883.6	0.5
AE	32728	100 Year	1161	22495	2.85	883.8	883.8	
	32728	FW	1152	23023	2.79	884.3	883.8	0.5
AF	33635	100 Year	1074	13252	4.84	883.8	883.8	
	33635	FW	868	11752	5.46	884.3	883.8	0.5
AG	34702	100 Year	960	10954	5.85	884.3	884.3	
	34702	FW	697	9666	6.63	884.7	884.3	0.4
AH	35697	100 Year	851	11924	5.34	885.5	885.5	
	35697	FW	582	10895	5.85	886.1	885.5	0.6
AI	36597	100 Year	901	13696	4.65	886.1	886.1	
	36597	FW	667	12626	5.05	886.6	886.1	0.5

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
AJ	37570	100 Year	780	11975	5.32	886.3	886.3	
	37570	FW	588	10667	5.97	886.9	886.3	0.6
AK	38643	100 Year	975	12939	4.92	887.0	887.0	
	38643	FW	612	9536	6.68	887.4	887.0	0.4
AL	39566	100 Year	1018	10209	6.24	887.2	887.2	
	39566	FW	556	8437	7.55	887.9	887.2	0.7
AM	40564	100 Year	1119	14029	4.54	889.1	889.1	
	40564	FW	561	10820	5.89	889.7	889.1	0.6
AN	41489	100 Year	985	16304	3.91	889.6	889.6	
	41489	FW	733	14415	4.42	890.3	889.6	0.7
AO	42501	100 Year	894	14985	4.25	889.8	889.8	
	42501	FW	662	13489	4.72	890.5	889.8	0.7
AP	43274	100 Year	893	15093	4.22	890.0	890.0	
	43274	FW	607	13367	4.77	890.7	890.0	0.7
AQ	44304	100 Year	873	14068	4.53	890.2	890.2	
	44304	FW	658	13220	4.82	891.0	890.2	0.8
AR	45346	100 Year	638	9896	6.44	890.5	890.5	
	45346	FW	490	9704	6.57	891.2	890.5	0.7
AS	46218	100 Year	919	14762	4.32	891.2	891.2	
	46218	FW	675	13323	4.78	891.9	891.2	0.7
AT	47126	100 Year	986	13662	4.66	891.4	891.4	
	47126	FW	832	13365	4.77	892.1	891.4	0.7

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
AU	48074	100 Year	1002	12116	5.26	891.9	891.9	
	48074	FW	688	10659	5.98	892.5	891.9	0.6
AV	49081	100 Year	963	12133	5.25	892.3	892.3	
	49081	FW	673	10971	5.81	892.9	892.3	0.6
AW	50071	100 Year	801	10600	6.01	892.8	892.8	
	50071	FW	448	8690	7.33	893.5	892.8	0.7
AX	50800	100 Year	773	14481	4.4	893.6	893.6	
	50800	FW	521	12218	5.22	894.3	893.6	0.7
AY	51780	100 Year	797	13214	4.82	893.8	893.8	
	51780	FW	612	11942	5.34	894.5	893.8	0.7
AZ	52765	100 Year	717	12874	4.95	894.4	894.4	
	52765	FW	545	11835	5.38	895.1	894.4	0.7
BA	53540	100 Year	717	10016	6.36	894.4	894.4	
	53540	FW	536	9199	6.93	895.2	894.4	0.8
BB	54414	100 Year	627	9170	6.95	895.2	895.2	
	54414	FW	409	8165	7.80	895.9	895.2	0.7
BC	55388	100 Year	649	13060	4.88	896.6	896.6	
	55388	FW	637	13496	4.72	897.3	896.6	0.7
BD	56328	100 Year	717	13118	4.86	897.0	897.0	
	56328	FW	602	12700	5.02	897.6	897.0	0.6
	57271	100 Year	739	20915	4.31	897.4	897.4	
	57271	FW	699	20528	4.32	898.0	897.4	0.6

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
	57431. BR D	100 Year	586	13082	5.8	897.3	897.3	
	57431. BR D	FW	590	13561	5.6	898.0	897.3	0.7
	57431. BR U	100 Year	712	13248	4.77	897.6	897.6	
	57431. BR U	FW	695	13678	4.62	898.2	897.6	0.6
	57609	100 Year	759	14085	4.49	897.7	897.7	
	57609	FW	744	14538	4.35	898.3	897.7	0.6
	58472	100 Year	731	15879	3.98	897.9	897.9	
	58472	FW	656	16000	3.95	898.5	897.9	0.6
	58574		Inl Struct					
	58664	100 Year	761	10732	5.89	901.1	901.1	
	58664	FW	657	10370	6.09	901.3	901.1	0.2
BE	59431	100 Year	689	12008	5.26	901.7	901.7	
	59431	FW	664	12001	5.26	901.9	901.7	0.2
BF	60288	100 Year	706	12318	5.13	902.0	902.0	
	60288	FW	650	11996	5.27	902.3	902.0	0.3
BG	61004	100 Year	511	10857	5.82	902.3	902.3	
	61004	FW	481	10838	5.83	902.6	902.3	0.3
	61679	100 Year	308	6616	9.55	902.2	902.2	
	61679	FW	257	6484	9.74	902.5	902.2	0.3
	61778. BR D	100 Year	302	6451	9.79	902.3	902.3	
	61778. BR D	FW	250	6315	10.0	902.5	902.3	0.2

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
	61778. BR U	100 Year	332	6055	10.43	902.3	902.3	
	61778. BR U	FW	298	6093	10.37	902.6	902.3	0.3
	61864	100 Year	347	6372	9.91	902.7	902.7	
	61864	FW	305	6388	9.89	903.0	902.7	0.3
BH	62840	100 Year	618	14077	4.47	904.5	904.5	
	62840	FW	578	13908	4.52	904.7	904.5	0.2
BI	63944	100 Year	575	8329	7.55	904.3	904.3	
	63944	FW	486	7640	8.23	904.4	904.3	0.1
BJ	64964	100 Year	820	10306	6.10	905.9	905.9	
	64964	FW	406	6808	9.23	905.9	905.9	0.0
BK	65993	100 Year	818	8900	7.06	907.0	907.0	
	65993	FW	402	6006	10.47	907.4	907.0	0.4
BL	67021	100 Year	1092	18191	3.81	909.1	909.1	
	67021	FW	823	15092	4.17	910.1	909.1	1.0
BM	67777	100 Year	1585	19814	3.23	909.4	909.4	
	67777	FW	1395	19903	3.16	910.4	909.4	1.0
BN	68787	100 Year	1474	19055	3.39	910.1	910.1	
	68787	FW	1286	17956	3.48	911.0	910.1	0.9
BO	69784	100 Year	1243	14191	4.56	910.4	910.4	
	69784	FW	934	12263	5.09	911.3	910.4	0.9
BP	70809	100 Year	1360	15586	3.88	911.4	911.4	
	70809	FW	1116	14709	4.08	912.3	911.4	0.9

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
BQ	71855	100 Year	836	12379	4.85	911.9	911.9	
	71855	FW	660	11504	5.22	912.7	911.9	0.8
BR	72875	100 Year	692	11799	5.09	912.4	912.4	
	72875	FW	537	10778	5.57	913.2	912.4	0.8
BS	73891	100 Year	647	11227	5.35	912.8	912.8	
	73891	FW	442	10041	5.98	913.7	912.8	0.9
BT	74874	100 Year	906	14357	4.18	913.4	913.4	
	74874	FW	609	12898	4.66	914.3	913.4	0.9
BU	75763	100 Year	880	14184	4.24	913.7	913.7	
	75763	FW	592	11716	5.13	914.5	913.7	0.8
BV	76550	100 Year	854	11359	5.29	913.8	913.8	
	76550	FW	481	8781	6.84	914.6	913.8	0.8
BW	77291	100 Year	732	9637	6.23	914.2	914.2	
	77291	FW	487	9132	6.58	915.2	914.2	1.0
BX	78047	100 Year	1202	16538	3.63	915.2	915.2	
	78047	FW	560	12293	4.89	916.0	915.2	0.8
BY	78764	100 Year	1002	18527	3.29	915.5	915.5	
	78764	FW	670	15571	3.86	916.4	915.5	0.9
BZ	79625	100 Year	727	15224	4.27	915.6	915.6	
	79625	FW	685	14385	4.18	916.5	915.6	0.9
CA	80555	100 Year	1028	12321	4.88	915.8	915.8	
	80555	FW	430	8403	7.15	916.6	915.8	0.8

Lettered Cross Section	River Station	Profile	Top Width, feet	Area, sq feet	Velocity, feet/second	Water Surface Elevation, feet	Base Water Surface Elevation, feet	Prof Delta Water Surface
CB	81469	100 Year	932	18813	3.74	916.7	916.7	
	81469	FW	487	12161	4.94	917.6	916.7	0.9
CC	82298	100 Year	859	17285	4.03	916.8	916.8	
	82298	FW	483	11682	5.14	917.7	916.8	0.9
CD	83075	100 Year	797	13689	4.39	917.1	917.1	
	83075	FW	395	10862	5.53	917.9	917.1	0.8
CE	83961	100 Year	880	16022	3.94	917.4	917.4	
	83961	FW	360	10425	5.76	918.2	917.4	0.8
CF	85117	100 Year	904	16427	3.63	917.8	917.8	
	85117	FW	439	12266	4.87	918.7	917.8	0.9

Appendix G

References

Dewberry, *LiDAR QA/QC - Quantitative and Qualitative Assessment Report – NY FEMA Flood Mitigation, LiDAR,* National Geospatial Technical Operation Center III, 1400 Independence Road, Rolla, MO 65401, September 14, 2007.

Federal Emergency Management Agency. *Flood Insurance Study, Borough of Great Bend, Susquehanna County, Pennsylvania*, Washington, D.C., March 1980.

Federal Emergency Management Agency. *Flood Insurance Study, Borough of Hallstead, Susquehanna County, Pennsylvania*, Washington, D.C., March 1980.

Federal Emergency Management Agency. *Flood Insurance Study, Borough of Lanesboro, Susquehanna County, Pennsylvania*, Washington, D.C., April 1980.

Federal Emergency Management Agency. *Flood Insurance Study, Borough of Oakland, Susquehanna County, Pennsylvania*, Washington, D.C., July 2, 1980.

Federal Emergency Management Agency. *Flood Insurance Study, Borough of Susquehanna Depot, Susquehanna County, Pennsylvania*, Washington, D.C., April 1980.

Federal Emergency Management Agency. *Flood Insurance Study, Township of Great Bend, Susquehanna County, Pennsylvania*, Washington, D.C., July 2, 1980.

Federal Emergency Management Agency. *Flood Insurance Study, Township of Harmony, Susquehanna County, Pennsylvania*, Washington, D.C., July 16, 1980.

Federal Emergency Management Agency. *Flood Insurance Study, Township of Oakland, Susquehanna County, Pennsylvania*, Washington, D.C., April 1980.

Federal Emergency Management Agency. *Guidelines and Specifications for Flood Hazard Mapping Partners,* Appendix A: Guidance for Aerial Mapping and Surveying, Washington, D.C., April 2003.

Federal Emergency Management Agency, *Guidelines and Specifications for Flood Hazard Mapping Partners,* Appendix N: Data Capture Standards, Washington, D.C., May 2005.

Flynn, K.M., Kirby, W.H., and Hummel, P.R. User's manual for program PeakFQ, Annual Flood Frequency Analysis Using Bulletin 17B Guidelines: U.S. Geological Survey Techniques and Methods Book 4, Chapter B4, 42 pgs. U.S. Geological Survey, Reston, VA, http://water.usgs.gov/software/PeakFQ/, 2006.

Pennsylvania Spatial Data Access (PASDA), http://www.pasda.psu.edu/, 2004.

URS Group Inc. and Dewberry. *Hydrology Report Susquehanna River Basin – Study, Susquehanna County*. Submitted to FEMA Region III, Philadelphia, PA, October 2007.

U.S. Army Corps of Engineers Hydrologic Engineering Center, *HEC-RAS Hydraulic Reference Manual*, Davis, CA, 2002.

U.S. Geological Survey, *Guide for Selecting Manning's Roughness Coefficients Natural Channels and Flood Plains*. U.S. Geological Survey Water-Supply Paper 2339. U.S. Geological Survey, Federal Center, Box 25425, Denver, CO 80225, 1989.

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Task Order 34
New York Flood Hazard Data Collection
FEMA-1649-DR-PA

Hydrology Report
Susquehanna River Basin – Study
Susquehanna County
OCTOBER 2007

Submitted to:

FEMA

Federal Emergency Management Agency, Region III
Philadelphia, PA

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1. Introduction

This study was conducted for the Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop new flood hazard information in the wake of the June and July 2006 flooding in the State of Pennsylvania. The effort will result in new flood hazard data for the Susquehanna River basin that will guide post-flood recovery efforts and that can be used later to update Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) for affected communities in Susquehanna County. The contractor will provide on-site and off-site technical support for Mitigation activities in the Joint Field Office (JFO), and will coordinate with State, local, and other Federal agencies to acquire and develop post-flood hazard data for use by Mitigation staff.

Rainfall starting on June 23 and continuing until July 10, 2006, caused record flooding in many areas of Pennsylvania. Severe concentrated rain caused water levels in rivers and creeks to rise quickly, resulting in record flooding of the Susquehanna River basin. Near record flood levels were recorded by the State and the U. S. Geological Survey (USGS) in these areas. Flood damage to existing structures was significant along the Susquehanna Rivers. In many of these watersheds, documented flood levels exceeded the existing base (1% annual chance) flood elevations and mapped Special Flood Hazard Areas as depicted on current FIRMs and FISs. The average age of these maps and studies is 20 years old. Some communities experienced severe flooding for the third consecutive year. Based on provisional analyses performed by the USGS, gage information on the Susquehanna River at Owego exceeded a 1% annual chance event.

This study developed peak flow discharges for the Susquehanna River. The post-flood peak flow discharges were developed for the 10%, 2%, 1%, and 0.2% annual chance (10-, 50-, 100-, and 500-year) events. Statistical analysis of stream gage data and discharge transfer equations were used for discharge computation.

The discharges developed in this study will be incorporated into the hydraulic analysis currently being developed for approximately 15 miles of the Susquehanna River.

The current study was conducted in accordance with the requirements of FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners* (Reference 11).

2. Susquehanna River

2.A. Watershed Description

The Susquehanna County portion of the Susquehanna River is located in the northeast region of Pennsylvania and flows in a westerly direction. Figure 2.1 depicts the location of the Susquehanna River Basin in relation to the States of New York and Pennsylvania.

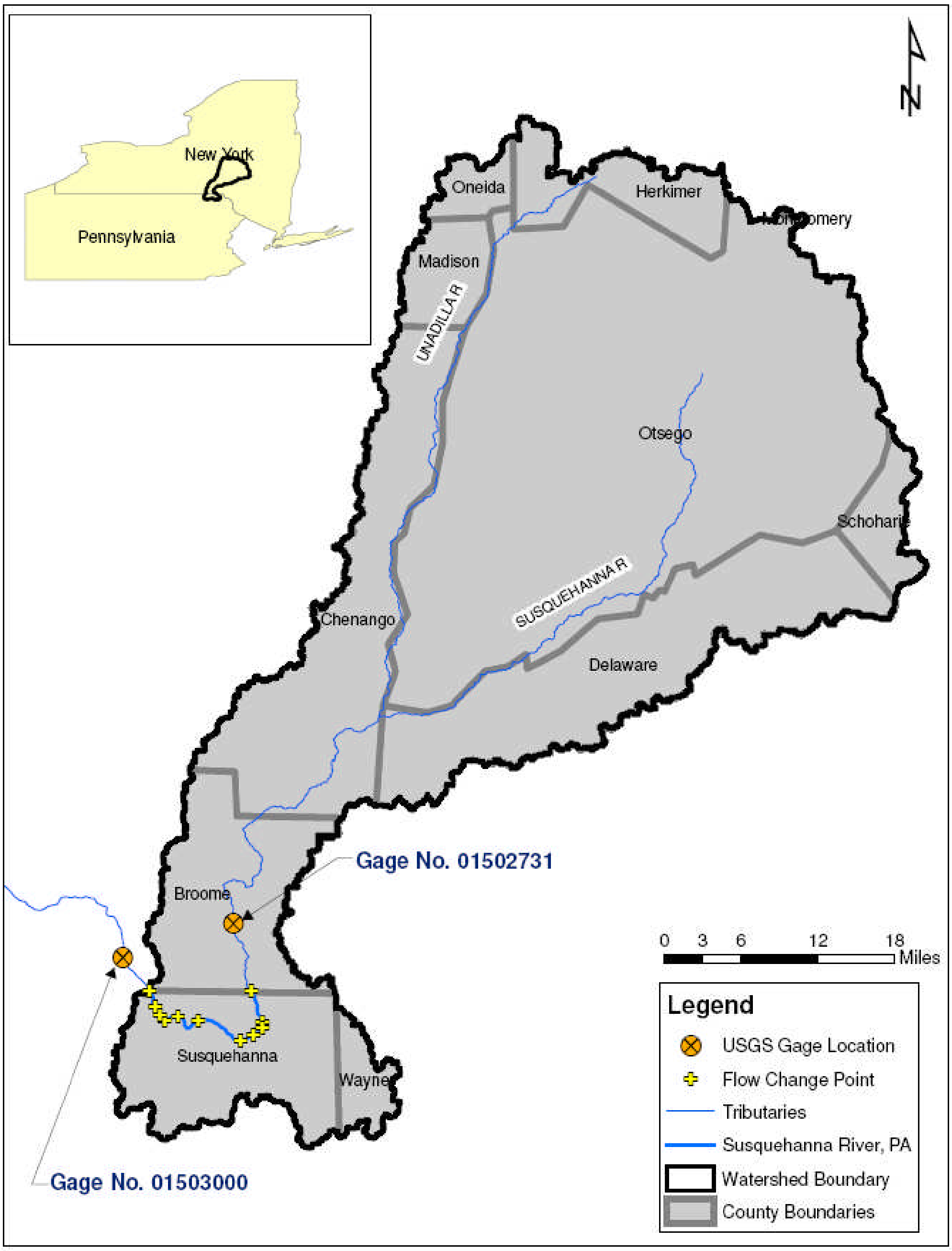

Figure 2.1. General Location of the Susquehanna River Basin

Figure 2.2 depicts the Susquehanna County portion of the Susquehanna River Basin with the discharge change locations and USGS gages.

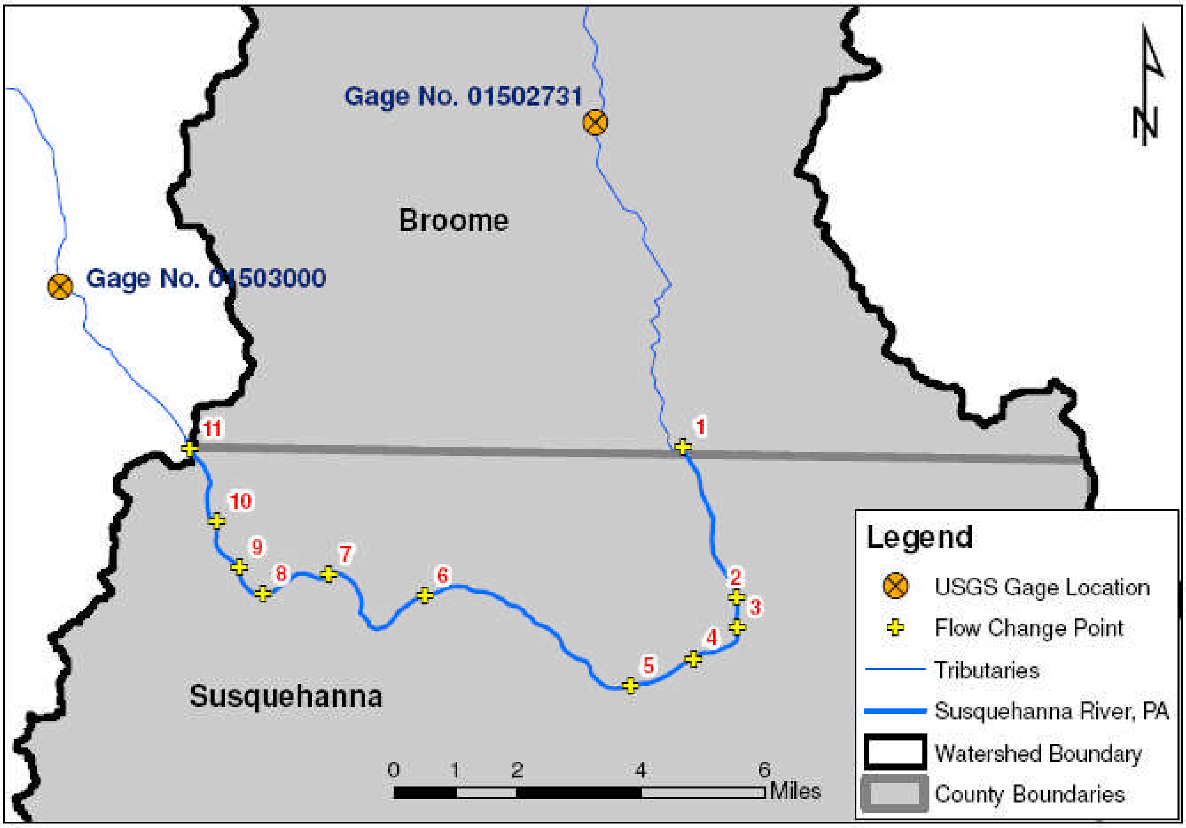

Figure 2.2. Susquehanna River Basin Pennsylvania Portion with Discharge Change Locations and USGS Gages

Although there are no active stream gages present along the reach of the Susquehanna River studied in Susquehanna County, Pennsylvania, there are two stream gages that influence the ungaged sites: USGS 01502731 and USGS 01503000. Table 2.1 shows the available record for these two gages.

Table 2.1. USGS Flow Gages Available along the Studied Reach of the Susquehanna River

USGS Gage No.	Gage Location	DA (Sq. mi.)	Record Historic Peaks	Systematic	Systematic Years
01502731	At Windsor, NY	1,820	N/A	1988-2006	19
01503000	At Conklin, NY	2,232	N/A	1913-2006	94

The main stream length of the Susquehanna River Pennsylvania Portion is approximately 15.6 miles.

The drainage area was calculated using 1 arc second (30 meters) Digital Elevation Model (DEM) downloaded from the USGS website (Seamless National Elevation Dataset) (Reference 15). A comparison was made between the delineated drainage basin area versus the contributing drainage area determined by USGS at the gages near the studied reach. There was a negligible discrepancy of 0.19% for the Windsor gage and 0.05% for the Conklin Gage between the calculated area and the area associated with the USGS gage data. It should be noted that the discharge calculations are not impacted by this drainage area discrepancy.

2.B. Historic Flood Events

The greatest known flood on the Susquehanna River occurred in June 2006 and was associated with extratropical storm Ernesto. Prior to the June 2006 flooding event, the flood of March 1936 was the greatest known historic flood on the Susquehanna River in Pennsylvania. Extreme floods have also occurred in 1913, April 1940, March 1964, and September 2004. The majority of large floods occur in the late-winter and early-spring months and result from a combination of moderate snow, sudden thaws with consequent melt off, and heavy rains (References 3-10).

2.C. Existing Watershed Studies

2.C.1. Flood Insurance Study

Peak discharges were defined in the various effective FISs dating from March 1980 to July 1980 for a total of 8 communities within Susquehanna County (see Table 2.2) (References 3-10). To develop the discharges, the effective FISs used discharge-frequency curves obtained from Pennsylvania Department of Environmental Protection (DEP), Water Resources Bulletin No.13 (Reference 2). The summary of the effective FIS 1% annual chance flow discharges defined at the various locations can be found in the Appendix.

Table 2.2. Effective Flood Insurance Studies for Susquehanna River Basin

County	Community	Effective Date
Susquehanna	Borough of Great Bend	Mar. 1980
	Township of Great Bend	Jul. 02, 1980
	Borough of Hallstead	Mar. 1980
	Borough of Lanesboro	Apr. 1980
	Township of Harmony	Jul. 16, 1980
	Borough of Susquehanna Depot	Apr. 1980
	Borough of Oakland	Jul. 02, 1980
	Township of Oakland	Apr. 1980

2.C.2. Magnitude and Frequency of Floods in New York, NY SIR (2006-5112)

The USGS, in cooperation with the New York State Department of Transportation, has developed regression equations based on Log Pearson Type III (LPIII) analyses conducted with annual peak stream flow records for New York. The results of the LPIII analyses are summarized in the 2006 USGS Scientific Investigations Report (SIR) 2006-5112, Magnitude and Frequency of Floods in New York (Reference 13). The report outlines the development of the New York Flood Frequency Tool to the six hydrologic regions in New York State. The report also outlines procedures for computing peak discharges for gaged and ungaged sites under varying circumstances. The weighted peak discharges for gaged and ungaged sites were obtained by using the methodology in SIR 2006-5112.

2.C.3. Water-Resources Investigations Report 00-4044 (WRI 00-4022)

WRI 00-4022 is a report on the development of a contour map showing generalized skew coefficients of annual peak discharges of rural, unregulated streams in New York, excluding Long Island (Reference 1). The generalized skew values for LPIII analysis were derived from the report's *Figure 1 – Generalized skew coefficients of New York, excluding Long Island*. The generalized skew standard deviation for all regions, found in the report's Table 1 page 7, was used for the LPIII analysis.

2.C.4. Water-Resources Investigations Report 00-4189 (WRI 00-4189)

Regression equations for estimating the magnitude and frequency of floods on ungaged streams in Pennsylvania with drainage areas less than 2,000 square miles were developed on the basis of peak-flow data collected at 313 streamflow-gaging stations and are summarized in WRI 00-4189 (Reference 16). *Table 1 – Regression coefficients for use with regression equations for peak flows on Pennsylvania streams,* and *Figure 2 - Carbonate Regions in Pennsylvania and Figure 3 – Flood Frequency regions in Pennsylvania* were used to compute the Pennsylvania *Regression Equations.*

2.D. Hydrologic Analysis

The 10%, 2%, 1%, and 0.2% annual chance peak discharges were developed for the Susquehanna River (Pennsylvania portion) at eleven locations along the studied reach. The 2006 flood event discharge was also determined for each discharge change location point for use in future hydraulic calibration analyses. For the two unregulated stream gages within New York at Windsor and Conklin, the discharges are weighted by using LPIII statistical analysis and New York Flood Frequency Regression Equations (see Section 2.D.1 and 2.D.2). LPIII statistical analysis is based on the systematic annual peak flow data recorded at the Windsor and Conklin gages. New York Flood Frequency Regression Equations are based on the hydrologic regions of New York and New York Flood Frequency Tool is used to compute the regression equations. For the ungaged sites, peak discharges were computed at all ungaged sites based on New York Flood Frequency Regression Equations. These discharges were weighted if the ungaged site's drainage area extends into an adjacent hydrologic region or state and/or if there is any single or dual stream gage influence. Although USGS gages 01502731 and 01503000 are located in New York, both gages influence ungaged sites and were, therefore, included in the analyses.

2.D.1. Gage Analysis

The LPIII analysis was applied to the annual peak flow record at Windsor and Conklin stream gages. The USGS PeakFQWin program was used in the analysis (Reference 17). This analysis is consistent with the guidelines described in Bulletin 17-B*: Guidelines for Determining Flood Flow Frequency*, Interagency Advisory Committee on Water Data, 1981 (Reference 12).

2.D.1.1. Systematic Record

The gage at Conklin has a systematic record from 1913, and the gage at Windsor has a systematic record from 1988. The historic peak flow record extends back to 1865 for Conklin gage. However, the systematic peak flow record from SIR 2006-5112 does not include peak discharges for 1865, and, therefore, it was not included in this study. The systematic records available for the Windsor and Conklin stream gages are summarized in Table 2.3.

Table 2.3. Annual Peak Discharges at Conklin and Windsor Stream Gages

Water Year	Stream Gage at Conklin 01503000			Stream Gage at Windsor 01502731		
	Date	Gage Height (feet)	Flow (cfs)	Date	Gage Height (feet)	Flow (cfs)
1913	Mar. 28, 1913	18.3	52,000[2]	-	-	-
1914	Mar. 30, 1914	18	47,000	-	-	-
1915	Jul. 08, 1915	16.15	40,500	-	-	-
1916	Apr. 02, 1916	16.49	42,100	-	-	-
1917	Mar. 28, 1917	13.54	28,700	-	-	-
1918	Oct. 30, 1917	13.73	29,400	-	-	-
1919	Oct. 31, 1918	10.65	17,900	-	-	-
1920	Mar. 29, 1920	15.05	35,200	-	-	-
1921	Mar. 10, 1921	13.17	27,100	-	-	-
1922	Nov. 29, 1921	16.03	39,900	-	-	-
1923	Mar. 24, 1923	13.23	27,300	-	-	-
1924	Sep. 30, 1924	16.86	44,000	-	-	-
1925	Feb. 12, 1925	17.04	44,900	-	-	-
1926	Apr. 10, 1926	14.04	30,600	-	-	-
1927	Mar. 15, 1927	14.81	33,600	-	-	-
1928	Oct. 19, 1927	16.88	43,500	-	-	-
1929	Mar. 17, 1929	17.6	47,000	-	-	-
1930	Dec. 20, 1929	10.9	18,600	-	-	-
1931	Mar. 30, 1931	12.16	22,800	-	-	-
1932	Apr. 01, 1932	13.75	29,000	-	-	-
1933	Oct. 08, 1932	13.1	25,000	-	-	-
1934	Mar. 05, 1934	13.2	25,400	-	-	-
1935	Jul. 09, 1935	16.95	41,900	-	-	-

Table 2.3. Annual Peak Discharges at Conklin and Windsor Stream Gages (continued)

Water Year	Stream Gage at Conklin 01503000			Stream Gage at Windsor 01502731		
	Date	Gage Height (feet)	Flow (cfs)	Date	Gage Height (feet)	Flow (cfs)
1936	Mar. 18, 1936	20.14	61,600	-	-	-
1937	Jan. 26, 1937	12.88	24,300	-	-	-
1938	Sep. 23, 1938	15.89	34,100	-	-	-
1939	Feb. 21, 1939	15.64	33,100	-	-	-
1940	Apr. 01, 1940	19.13	51,800	-	-	-
1941	Apr. 06, 1941	13.4	24,900	-	-	-
1942	Mar. 19, 1942	14.45	28,100	-	-	-
1943	Dec. 31, 1942	18.76	48,600	-	-	-
1944	Mar. 18, 1944	14.8	30,000	-	-	-
1945	Mar. 18, 1945	14.17	27,500	-	-	-
1946	Mar. 09, 1946	15.49	32,900	-	-	-
1947	Apr. 06, 1947	15.04	31,000	-	-	-
1948	Mar. 22, 1948	20.83	60,500	-	-	-
1949	Dec. 31, 1948	14.39	28,400	-	-	-
1950	Mar. 29, 1950	15.87	34,600	-	-	-
1951	Dec. 04, 1950	16.2	36,100	-	-	-
1952	Mar. 12, 1952	13.4	24,700	-	-	-
1953	Jan. 25, 1953	13.61	25,400	-	-	-
1954	Feb. 18, 1954	14.55	29,000	-	-	-
1955	Mar. 13, 1955	12.72	22,500	-	-	-
1956	Apr. 07, 1956	16.04	39,200	-	-	-
1957	Jan. 23, 1957	11.74	21,400	-	-	-
1958	Apr. 07, 1958	15.83	38,300	-	-	-

Table 2.3. Annual Peak Discharges at Conklin and Windsor Stream Gages (continued)

Water Year	Stream Gage at Conklin 01503000			Stream Gage at Windsor 01502731		
	Date	Gage Height (feet)	Flow (cfs)	Date	Gage Height (feet)	Flow (cfs)
1959	Jan. 22, 1959	14.49	32,300	-	-	-
1960	Apr. 06, 1960	17.02	44,000	-	-	-
1961	Feb. 26, 1961	16.02	39,100	-	-	-
1962	Apr. 01, 1962	15.17	35,300	-	-	-
1963	Mar. 28, 1963	15.73	37,800	-	-	-
1964	Mar. 10, 1964	18.26	50,200	-	-	-
1965	Feb. 10, 1965	9.81	14,900	-	-	-
1966	Mar. 06, 1966	10.68	18,000	-	-	-
1967	Mar. 30, 1967	10.3	16,800	-	-	-
1968	Mar. 23, 1968	11.63	21,200	-	-	-
1969	Nov. 19, 1968	-	24,000	-	-	-
1970	Apr. 03, 1970	12.54	25,300	-	-	-
1971	Mar. 16, 1971	11.51	21,700	-	-	-
1972	Jun. 23, 1972	12.89	26,500	-	-	-
1973	Nov. 09, 1972	14.4	32,100	-	-	-
1974	Dec. 28, 1973	12.43	24,900	-	-	-
1975	Feb. 25, 1975	14.05	30,700	-	-	-
1976	Oct. 19, 1975	14.31	31,700	-	-	-
1977	Mar. 16, 1977	16.9	43,400	-	-	-
1978	Oct. 19, 1977	16.28	40,300	-	-	-
1979	Mar. 07, 1979	17.25	45,200	-	-	-
1980	Mar. 22, 1980	12.59	25,400	-	-	-
1981	Feb. 21, 1981	12.39	24,700	-	-	-

Table 2.3. Annual Peak Discharges at Conklin and Windsor Stream Gages (continued)

Water Year	Stream Gage at Conklin 01503000			Stream Gage at Windsor 01502731		
	Date	Gage Height (feet)	Flow (cfs)	Date	Gage Height (feet)	Flow (cfs)
1982	Mar. 27, 1982	10.31	17,700	-	-	-
1983	Apr. 16, 1983	13.84	29,800	-	-	-
1984	Dec. 14, 1983	17.17	44,700	-	-	-
1985	Sep. 28, 1985	11.04	20,000	-	-	-
1986	Mar. 15, 1986	17.1	44,400	-	-	-
1987	Nov. 27, 1986	12.5	25,100	-	-	-
1988	May. 20, 1988	11.49	21,500	Mar. 27, 1988	12.16	16,700
1989	May. 07, 1989	12.48	25,000	May 07, 1989	13.39	19,900
1990	Feb. 17, 1990	11.12	20,300	Feb. 17, 1990	13.31	19,700
1991	Oct. 24, 1990	12.18	24,000	Nov. 11, 1990	12.69	18,100[2]
1992	Mar. 12, 1992	9.46	15,100	Mar. 12, 1992	10.54	12,900
1993	Apr. 01, 1993	17.91	48,500	Apr. 01, 1993	19.45	37,200
1994	Apr. 07, 1994	13.42	28,300	Apr. 07, 1994	15.01	24,100
1995	Mar. 09, 1995	9.63	15,600	Mar. 09, 1995	10.80	13,500
1996	Jan. 19, 1996	17.55	46,600[2,9]	Jan. 20, 1996	21.22	40,000[2,9]
1997	Dec. 02, 1996	14.29	31,600	Dec. 02, 1996	16.18	27,400
1998	Jan. 10, 1998	15.42	36,400	Jan. 10, 1998	18.60	34,600
1999	Jan. 24, 1999	14.89	34,100	Jan. 24, 1999	16.96	29,700
2000	Feb. 28, 2000	15.78	38,000	Feb. 28, 2000	18.05	32,900
2001	Apr. 11, 2001	13.58	28,900	Apr. 11, 2001	16.42	28,100
2002	Mar. 27, 2002	12.09	23,700	Mar. 27, 2002	13.48	20,100
2003	Mar. 23, 2003	14.73	33,500	Mar. 23, 2003	17.09	30,000
2004	Sep. 18, 2004	19.01	54,700	Sep. 18, 2004	15.98	26,400

Table 2.3. Annual Peak Discharges at Conklin and Windsor Stream Gages (continued)

Water Year	Stream Gage at Conklin 01503000			Stream Gage at Windsor 01502731		
	Date	Gage Height (feet)	Flow (cfs)	Date	Gage Height (feet)	Flow (cfs)
2005	Apr. 03, 2005	18.08	49,400	Apr. 04, 2005	19.09	35,200
2006	Jun. 28, 2006	-	76,800	Jun. 29, 2006	24.27	55,900[7]

Flow Qualification Codes.

- [2] -- Discharge is an Estimate
- [7] -- Discharge is an Historic Peak
- [9] -- Discharge due to Snowmelt, Hurricane, Ice-jam, or Debris Dam breakup
- - -- Data is not available

2.D.1.2. Skew Coefficient

The weighted skew, as opposed to the generalized and station skew, was used in the analysis because both of the gages are unregulated based on Table 10 in SIR 2006-5112 (Reference 13). The generalized skew coefficient was updated in the PeakFQWin input files based on the generalized skew coefficients of New York from Figure 1 of USGS WRI 00-4022 (Reference 1). The generalized skew standard error was also updated based on Table 6 of SIR 2006-5112 Regional values. Table 2.4 summarizes the skew coefficients for both gages used in the analyses.

Table 2.4. Variables Used for LPIII Analyses

Gage No.	Gage Name	Variables for LP-III Analysis			
		Systematic Years of Record	D.A. (sq mi)	Gen Skew	Gen Skew Std Error
01502731	Windsor	19	1,853.9	-0.009	0.321
01503000	Conklin	94	2,232	0.053	0.321

2.D.1.3. Outliers

High outliers: There were no high outliers computed by the PeakFQWin program that were larger than the highest recorded peak discharge. Therefore, no recorded peak flows were excluded as high outliers (Figures 2.3 and 2.4).

Low outliers: There were no low outliers computed by the PeakFQWin program that were below the lowest recorded peak discharge for the Windsor and Conklin gages. Therefore, no recorded peak flows were excluded as low outliers for these two gages (Figures 2.3 and 2.4).

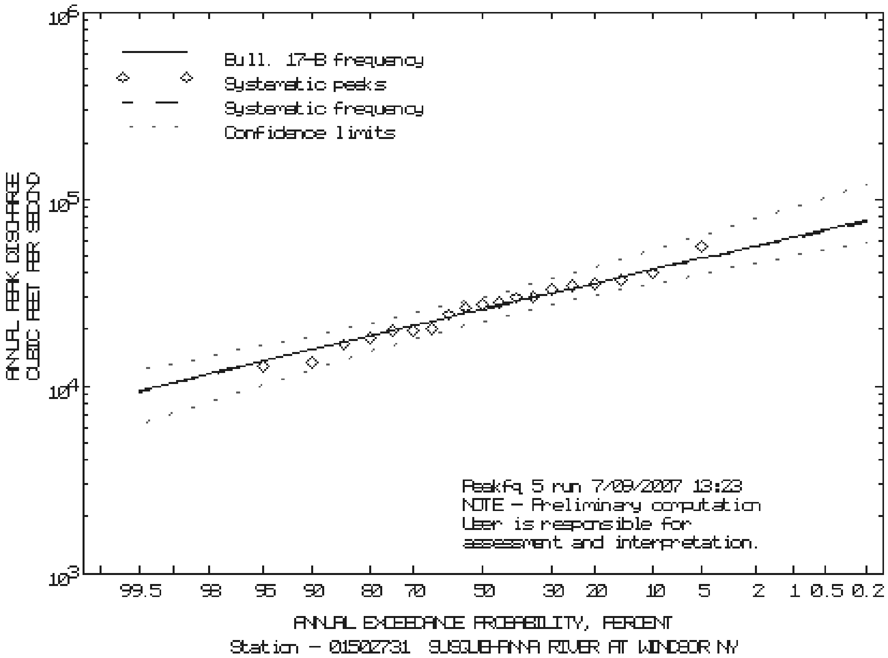

Figure 2.3. Probability Plotting Position at Gage 01502731 (at Windsor)

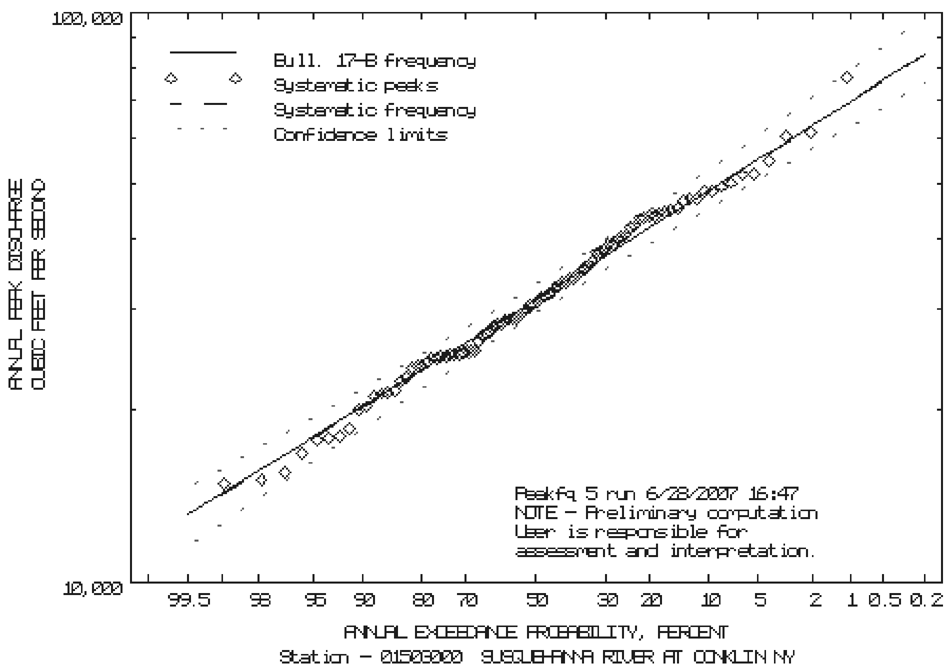

Figure 2.4. Probability Plotting Position at Gage 01503000 (at Conklin)

2.D.2. Peak Discharge Computation

The USGS SIR 2006-5112 recommends weighting the statistical analysis result with the regression equation estimates (Reference 13). The New York regression equations yielded slightly different discharges than those reported in SIR 2006-5112 for regression equations. For instance, SIR 2006-5112 reports a regression equation discharge of 53,600 cfs at the Windsor gage for 1% annual chance peak discharge; New York Flood Frequency Tool (NYFF) yielded 55,300 cfs. At the Conklin gage, NYFF and the SIR 2006-5112 regression discharge matched at 65,900 cfs for 1% annual chance peak discharge.

The regional regression equations are used to improve streamflow-gaging station estimates (based on LPIII flood-frequency analysis of the gaged annual peak-discharge record) by using a weighted average of the two estimates (regression and gaged). The weighted-average discharges are computed from Equation 3 from SIR 2006-5112, page 35 (Reference 13):

$$Q_{T(w)} = \frac{Q_{T(g)}(N) + Q_{T(r)}(E)}{N + E} \qquad (1)$$

Where,

$Q_{T(w)}$ is weighted peak discharge at the gaged site , in cfs, for *T*-year recurrence interval

$Q_{T(g)}$ is the peak discharge at gage, in cfs, calculated through LPIII frequency analysis of the station's peak discharge record, for the *T*-year recurrence interval

N is the number of years of annual peak-discharge record used to calculate $Q_{T(g)}$ at the gaging station

$Q_{T(r)}$ is the regional regression estimate of the peak discharge at the gaged site, in cfs, for the *T*-year recurrence interval

E is the average equivalent years of record associated with the regression equation (Table 2 in SIR 2006-5112) that was used to calculate $Q_{T(r)}$

The following methods from SIR 2006-5112 were used to estimate the peak discharges of selected recurrence intervals for ungaged sites:

1) If the drainage area of an ungaged site extends into an adjacent hydrologic region or state, the percentage that lies within each hydrologic region and (or) state is estimated. Peak discharge estimates are computed by using the National Flood Frequency Program, Version 3 (Reference 14) for the entire drainage basin through each of the appropriate regional or state equations, and the drainage-area percentages are used as weighting factors by multiplying the percentages by the corresponding peak-discharge estimate; the resulting values are then summed to compute the peak discharge for the entire basin.

To estimate the peak flows for Pennsylvania, the regression equations from Pennsylvania WRI 00-4189 were used (Reference 16). Susquehanna Basin (Pennsylvania portion) lies within Region A according to *Figure 3. Flood frequency regions in Pennsylvania in PA WRI 00-4189.* The following equations were applied to get the peak discharges for *T*-year recurrence interval:

$$
\begin{aligned}
Q_{10} &= 334.4DA^{.7770}(1+.01F)^{-.9712}(1+.01U)^{1.0217}(1+.01C)^{-1.7184}(1+0.1CA)^{-.5179} \\
Q_{50} &= 698.4DA^{.7414}(1+.01F)^{-1.0821}(1+.01U)^{.5785}(1+.01C)^{-1.3955}(1+0.1CA)^{-.4980} \\
Q_{100} &= 925.8DA^{.7278}(1+.01F)^{-1.1342}(1+.01U)^{.4040}(1+.01C)^{-1.2691}(1+0.1CA)^{-.4637} \\
Q_{500} &= 1{,}696DA^{-.6994}(1+.01F)^{-1.2666}(1+.01U)^{.0208}(1+.01C)^{-.9877}(1+0.1CA)^{-.3834}
\end{aligned}
\tag{2}
$$

Where

Q_T	is return interval peak flow, in cfs
DA	is the drainage area, in square miles
F	is the percentage of forest cover, in percent
U	is the percentage of urban development, in percent
C	is the percentage of basin underlain by carbonate rock, in percent
CA	is the percentage of basin controlled by lakes, swamps, or reservoirs, in percent

It can be seen that Susquehanna Basin's percentage of underlain Carbonate Rock values are negligible based on *Figure 2. Carbonate regions in Pennsylvania in PA WRI 00-4189*. "*F*", "*U*", "*C*" values are computed per basin using GIS overlay analysis from Pennsylvania landcover data.

2) If the ungaged site for which flood-frequency estimate is on a gaged stream, and if the site's drainage area is between 50% and 150% of the drainage area of the stream gage, the weighted estimate for the ungaged site can be computed by the following equation (pages 35 and 36, Equations 4 and 5 in SIR 2006-5112) (Reference 13):

$$Q_{T(U)w} = \frac{2\Delta A}{A_g} Q_{T(U)r} + (1 - \frac{2\Delta A}{A_g}) Q_{T(U)g} \tag{3a}$$

$$Q_{T(U)g} = (\frac{Au}{A_g})^b Q_{T(w)} \tag{3b}$$

Where,

$Q_{T(U)w}$ is the weighted estimate of discharge Q_T for recurrence interval T at the ungaged site

ΔA *is the absolute value of difference between the drainage areas of the streamflow-gaging station, (A_g) and the ungaged site, (A_u)*

$Q_{T(U)r}$ is the peak flow estimate for recurrence interval at the ungaged site, derived from applicable regional equations

$Q_{T(U)g}$ is the peak flow estimate for recurrence interval T at the ungaged site, derived from the weighted estimate of peak discharge at the streamflow-gaging station $Q_{T(U)w}$

b is the exponent from the appropriate drainage area-only equation for Hydrologic Regions 4 (page 34, Table 3 in SIR 2006-5112) which can be seen in *Table 2.5a*. *Table 2.5b* values are taken from WRI 00-4189, page 9, Table 1, Region A. *Table 2.5c* value is calculated based on known 2006 peak discharges at the gages using the above referenced Equation 3b.

Table 2.5a. "b" Values Used for Region 4

Recurrence Interval	Power
10% annual chance	0.775
2% annual chance	0.751
1% annual chance	0.743
0.2% annual chance	0.727

Table 2.5b. "b" Values Used for PA

Recurrence Interval	Power
10% annual chance	0.777
2% annual chance	0.741
1% annual chance	0.728
0.2% annual chance	0.699

Table 2.5c. "b" Values Used for Transferring 2006 Gage Data to Ungaged Sites

Downstream Gage – Upstream Gage	Power
01502731 - 01503000	1.707

3) If the ungaged site is on a gaged stream and lies between two gaging stations, the following equation is used (page 36, Equation 6 in SIR 2006-5112) (Reference 13):

$$Q_{T(uf)w} = \left[Q_{T(u1)w}\left(A_{g2} - A_u\right) + Q_{T(u2)w}\left(A_u - A_{g1}\right)\right] / \left(A_{g2} - A_{g1}\right) \qquad (4)$$

Where,

$Q_{T(uf)w}$ is final weighted flow estimate for the ungaged site between gaging stations

$Q_{T(u1)w}$ is the weighted flow estimate computed for the ungaged site from the upstream gage records as described in the method above

A_{g2} is the drainage area of the downstream gage

A_u is the drainage area of the ungaged site

$Q_{T(u1)w}$ is the weighted flow estimate computed for the ungaged site from the downstream gage records as described in the method above

A_{g1} is the drainage area of the upstream gage

Susquehanna Basin lies within Hydrologic Region 4 of adjacent State of New York, and in Region A of Pennsylvania. Most of the drainage area lies within Hydrologic Region 4; therefore, the New York Flood Frequency Tool was run to get the regression discharge values from different storm events. Since the studied reach is in Pennsylvania, the Pennsylvania regression equations were applied as well to maintain consistency with surrounding streams in Pennsylvania. The application of the Pennsylvania regression equations had minimal impact on the computed discharges.

After the weighted peak discharges were computed based on regression analysis, the gage influence was checked for 11 ungaged site locations based on Table 2.5d. All the ungaged sites have dual gage influence because their drainage areas are within the upstream and downstream range limits (method 3 was applied).

Table 2.5d. US and DS Limits to Check Gage Influence

Gages	D.A. (sq mi)	US Range Limit	DS Range Limit
1502731	1854.0	927.0	2781.0
1503000	2233.0	1116.5	3349.5

After method 3 was applied, the discharges were weighted based on the drainage area percentages for each hydrologic region.

2.D.3. Recommended Discharges for Hydraulic Analysis

The final recommended discharges are depicted in Table 2.6. For ungaged sites, the three methodologies in SIR 2006-5112 were used based on the location of the ungaged site (Reference 13).

Table 2.6. Recommended Discharges for Hydraulic Analysis

ID	Description	DA (Sq.Mi)	Q10-Yr (cfs)	Q50-Yr (cfs)	Q100-Yr (cfs)	Q500-Yr (cfs)	Q_2006 (cfs)
1	Upstream Study Limit - NY/PA State Line	1,887	41,626	54,389	59,691	71,674	57,608
2	Effective FIS Location - U/S of Starruca Creek	1,905	41,911	54,747	60,079	72,142	58,544
3	U/S of Canawacta Creek	1,981	43,500	56,826	62,399	75,059	62,611
4	U/S of Drinker Creek	1,995	43,814	57,237	62,859	75,649	63,402
5	Effective FIS Study- D/S of Oakland and Susquehanna Depot & D/S of Inline Structure	2,005	44,031	57,518	63,172	76,064	63,914
6	U/S of Mitchell Creek	2,022	44,386	57,999	63,723	76,778	64,831
7	U/S of Unnamed Tributary to Susquehanna River	2,037	44,654	58,371	64,130	77,308	65,681
8	U/S of Salt Lick Creek	2,043	44,754	58,492	64,270	77,498	66,030
9	Effective FIS Location - Downstream of Hallstead and U/S of DuBois Creek	2,084	45,695	59,747	65,669	79,279	68,268
10	U/S of Town Bridge Creek	2,097	45,991	60,125	66,087	79,806	69,040
11	Downstream study limit - NY/PA State Line & Effective FIS Location - D/S of Township of Great Bend	2,118	46,364	60,594	66,594	80,427	70,210

2.D.4. Discussion of Results

The 1% annual chance discharges developed in this study are compared with other available study results in Table 2.7. The discharges calculated for the Windsor and Conklin stream gages are 5% higher than the USGS weighted discharges in Table 8 in SIR 2006-5112 (Reference 13). The discharges computed for the Windsor and Conklin gage locations in this study are based on a statistical analysis of recorded peak flows and are an appropriate estimate of the peak flow discharges for these locations.

The new study’s discharges range between 9.9% and 15.8% of the effective FIS estimate for peak flows for 1% annual chance peak discharges (see Figure 2.5). One of the main reasons for this difference is that the new study used a different methodology than the effective FIS. Also, discharge locations described in the FIS study are difficult to identify accurately since 3 different drainage areas have the same discharge values. Overall, this study was based on the guidelines of Bulletin 17-B: Guidelines for Determining Flood Flow Frequency and SIR 2006-5112 (References 12 and 13, respectively) and the results are reasonable.

Table 2.7. New Discharges Compared with FIS and USGS Study in SIR 2006-5112

No.	Effective Info				New Info		Percent Change
	Location	Town/Village/City	DA (mi^2)	Q100 (cfs)	DA (mi^2)	Q100 (cfs)	
N/A	At USGS gage station No. 01502731 at Windsor New York	Windsor, NY	1,820	56,100	1,854	59,089	5.3%
2	Effective FIS Location - U/s of Starruca Creek	Township of Oakland / Susquehanna Co.	1,912	52,500	1,905	60,079	14.4%
5	Effective FIS Study- D/s of Oakland and Susquehanna Depot	Borough of Susquehanna Depot/ Susquehanna, Co.	2,001	57,500	2,005	63,172	9.9%
7	Effective FIS Location - Downstream of Hallstead	Borough of Hallstead/ Susquehanna, Co.	2,100	57,500	2,097	65,669	14.2%
11	Downstream study limit - NY/PA State Line & Effective FIS Location - d/s of Township of Great Bend	Township of Greatbend/ Susquehanna, Co.	2,117	57,500	2,118	66,594	15.8%
N/A	At USGS Gage No. 01503000 in Conklin New York	Conklin, NY	2,232	65,800	2,233	69,186	5.1%

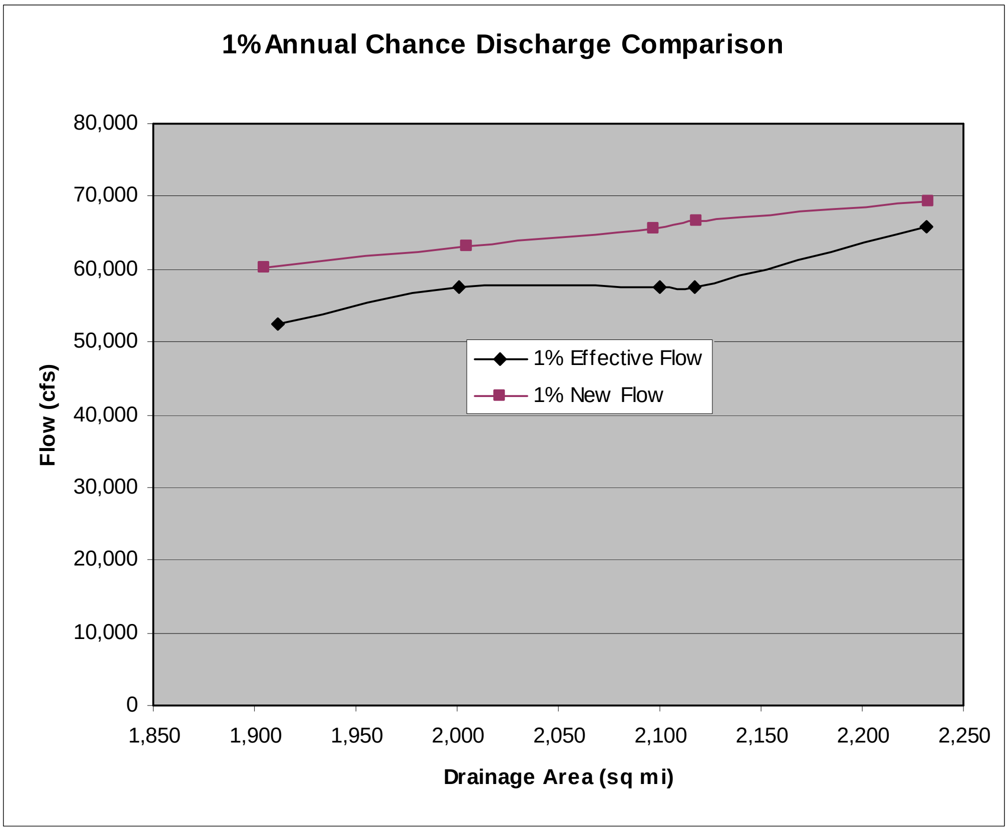

Figure 2.5. 1% Annual Chance Discharge Comparison of New Flows and Effective Flows

2.E. References

1) Development of a Contour Map Showing Generalized Skew Coefficients of Annual Peak Discharges of Rural, Unregulated Streams in New York, Excluding Long Island; USGS Water Resources Investigations Report 00-4022.
2) Floods in Pennsylvania. Flippo, H.N., Jr. USGS and DEP, Water Resources Bulletin No. 13. 59 pp.
3) Flood Insurance Study, Borough of Hallstead, Susquehanna County, PA, Federal Emergency Management Agency, March, 1980
4) Flood Insurance Study, Borough of Great Bend, Susquehanna County, PA, Federal Emergency Management Agency, March, 1980.
5) Flood Insurance Study, Borough of Lanesboro, Susquehanna County, PA, Federal Emergency Management Agency, April, 1980.
6) Flood Insurance Study, Borough of Oakland, Susquehanna County, PA, Federal Emergency Management Agency, July 2, 1980
7) Flood Insurance Study, Borough of Susquehanna Depot, Susquehanna County, PA, Federal Emergency Management Agency, April, 1980
8) Flood Insurance Study, Township of Great Bend, Susquehanna County, PA, Federal Emergency Management Agency, July 2, 1980.
9) Flood Insurance Study, Township of Harmony, Susquehanna County, PA, Federal Emergency Management Agency, July 16, 1980.
10) Flood Insurance Study, Township of Oakland, Susquehanna County, PA, Federal Emergency Management Agency, April, 1980
11) Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix N: Data Capture Standards, Federal Emergency Management Agency, May 2005.
12) Guidelines for Determining Flood Flow Frequency, Interagency Advisory Committee on Water Data, Bulletin 17-B. 1981.
13) Magnitude and Frequency of Floods in New York; USGS Scientific Investigations Report 2006-5112.
14) National Flood Frequency Program, Version 3: A Computer Program for Estimating Magnitude and Frequency of Floods for Ungaged Sites, USGS Water Resources Investigations Report 02-4168.
15) Seamless National Elevation Dataset, United States Geological Service, 2006; http://search.usgs.gov/query.html?col=usgs%2Bfaq&rq=1&qt=seamless+national+elevation
16) Techniques for Estimating Magnitude and Frequency of Peak Flows for Pennsylvania Streams by Marla H. Stuckey and Lloyd A. Reed, Water Resources Investigations Report 00-4189.
17) User's Manual for Program PeakFQ, Annual Flood-Frequency Analysis Using Bulletin 17B Guidelines.

APPENDIX

Susquehanna River Effective FIS Summary Table for Susquehanna County

S.No	FIS Name/Date	Discharge Location in Effective FIS	Effective DA (sq mi)	Effective 100-yr Q (cfs)	Study Completion	Hydrology - FIS	Hydraulics - FIS	Mannings n-value
1	Borough of Great Bend, Pennsylvania, Susquehanna County (03/1980)	At the downstream corporate limits	2,100	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program; n-values field inspection	channel n = 0.025 overbank n = 0.120
2	Township of Great Bend, Pennsylvania, Susquehanna County (07/02/1980)	At the downstream corporate limits	2,117	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program; n-values field inspection	channel n = 0.025 overbank n = 0.120
3	Borough of Hallstead, Pennsylvania, Susquehanna County (03/1980)	At the downstream corporate limits	2,100	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program	channel n = 0.025 overbank n = 0.120
4	Borough of LanesBoro Pennsylvania, Susquehanna County (04/1980)	At the downstream corporate limits	2,001	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program	channel n = 0.025 overbank n = 0.120
		Upstream of Starucca Creek	1,912	52,500				
5	Township of Harmony, Pennsylvania, Susquehanna County (07/16/1980)	At the downstream corporate limits of the Borough of Lanesboro	2,001	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program	channel n = 0.025 overbank n = 0.120
		Upstream of Starucca Creek	1,912	52,500				
6	Borough of Susquehanna Depot, Pennsylvania, Susquehanna County (04/1980)	At the downstream corporate limits	2,001	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program; n-values field inspection	channel n = 0.025 overbank n = 0.120

7	Borough of Oakland, Pennsylvania, Susquehanna County (07/02/1980)	At the downstream corporate limits	2,001	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program; n-values field inspection	channel n = 0.025 overbank n = 0.120
8	Township of Oakland Pennsylvania, Susquehanna County (04/1980)	At the Power Plant Dam	2,001	57,500	Jul-79	Discharge frequency curves obtained from Pennsylvania DEP, Water Resources Bulletin No. 13	Water surface elevations were computed using COE HEC-2 program; n-values field inspection	channel n = 0.025 overbank n = 0.120
		Upstream of Starucca Creek	1,912	52,500				

PeakFQ Outputs

GAGE 01503000

```
  Program PeakFq          U. S. GEOLOGICAL SURVEY            Seq.000.000
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
  05/06/2005          following Bulletin 17-B Guidelines       06/28/2007 16:47

                         --- PROCESSING OPTIONS ---

                      Plot option         = Graphics device
                      Basin char output   = WATSTORE
                      Print option        = Yes
                      Debug print         = No
                      Input peaks listing = Long
                      Input peaks format  = WATSTORE peak file

                      Input files used:
                         peaks (ascii)  - Q:\50005446\CAD\CIVIL\HYDROLOGY\PEAK FQ
RUNS\TIN SKEW\GAGE 01503000\1503000-PEAK
                         specifications - PKFQWPSF.TMP
                      Output file(s):
                         main - Q:\50005446\CAD\CIVIL\HYDROLOGY\PEAK FQ RUNS\TIN
SKEW\GAGE 01503000\1503000-PEAK
                         bcd  - 1503000-PEAK.BCD

1

  Program PeakFq          U. S. GEOLOGICAL SURVEY            Seq.001.001
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
  05/06/2005          following Bulletin 17-B Guidelines       06/28/2007 16:47

              Station - 01503000  SUSQUEHANNA RIVER AT CONKLIN NY


                    I N P U T   D A T A   S U M M A R Y

                 Number of peaks in record            =       94
                 Peaks not used in analysis           =        0
                 Systematic peaks in analysis         =       94
                 Historic peaks in analysis           =        0
                 Years of historic record             =        0
                 Generalized skew                     =    0.053
                      Standard error                  =    0.321
                      Mean Square error               =    0.103
                 Skew option                          =   WEIGHTED
                 Gage base discharge                  =      0.0
                 User supplied high outlier threshold =   --
```

User supplied low outlier criterion = --
Plotting position parameter = 0.00

********* NOTICE -- Preliminary machine computations. *********
********* User responsible for assessment and interpretation. *********

WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE. 0.0
WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION. 11298.6
WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE. 86985.3

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.002
Ver. 5.0 Beta 8 Annual peak flow frequency analysis Run Date / Time
05/06/2005 following Bulletin 17-B Guidelines 06/28/2007 16:47

Station - 01503000 SUSQUEHANNA RIVER AT CONKLIN NY

ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

	FLOOD BASE		LOGARITHMIC		
	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	4.4962	0.1479	0.012
BULL.17B ESTIMATE	0.0	1.0000	4.4962	0.1479	0.027

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	13150.0	13090.0	12850.0	11500.0	14660.0
0.9900	14290.0	14240.0	14030.0	12620.0	15800.0
0.9500	17950.0	17920.0	17790.0	16270.0	19470.0
0.9000	20280.0	20270.0	20170.0	18620.0	21810.0
0.8000	23530.0	23530.0	23460.0	21890.0	25070.0
0.6667	27040.0	27050.0	27010.0	25380.0	28670.0
0.5000	31300.0	31330.0	31300.0	29530.0	33180.0
0.4292	33260.0	33290.0	33280.0	31400.0	35310.0
0.2000	41740.0	41750.0	41860.0	39160.0	44860.0
0.1000	48550.0	48530.0	48830.0	45150.0	52890.0
0.0400	57090.0	56990.0	57670.0	52450.0	63260.0
0.0200	63410.0	63240.0	64310.0	57740.0	71100.0
0.0100	69710.0	69450.0	71030.0	62950.0	79040.0
0.0050	76030.0	75680.0	77870.0	68110.0	87130.0
0.0020	84490.0	83980.0	87180.0	74940.0	98100.0

```
Program PeakFq           U. S. GEOLOGICAL SURVEY           Seq.001.003
Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
05/06/2005          following Bulletin 17-B Guidelines      06/28/2007 16:47
              Station - 01503000  SUSQUEHANNA RIVER AT CONKLIN NY
                         I N P U T   D A T A   L I S T I N G
```

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1913	52000.0		1960	44000.0	
1914	47000.0		1961	39100.0	
1915	40500.0		1962	35300.0	
1916	42100.0		1963	37800.0	
1917	28700.0		1964	50200.0	
1918	29400.0		1965	14900.0	
1919	17900.0		1966	18000.0	
1920	35200.0		1967	16800.0	
1921	27100.0		1968	21200.0	
1922	39900.0		1969	24000.0	
1923	27300.0		1970	25300.0	
1924	44000.0		1971	21700.0	
1925	44900.0		1972	26500.0	
1926	30600.0		1973	32100.0	
1927	33600.0		1974	24900.0	
1928	43500.0		1975	30700.0	
1929	47000.0		1976	31700.0	
1930	18600.0		1977	43400.0	
1931	22800.0		1978	40300.0	
1932	29000.0		1979	45200.0	
1933	25000.0		1980	25400.0	
1934	25400.0		1981	24700.0	
1935	41900.0		1982	17700.0	
1936	61600.0		1983	29800.0	
1937	24300.0		1984	44700.0	
1938	34100.0		1985	20000.0	
1939	33100.0		1986	44400.0	
1940	51800.0		1987	25100.0	
1941	24900.0		1988	21500.0	
1942	28100.0		1989	25000.0	
1943	48600.0		1990	20300.0	
1944	30000.0		1991	24000.0	
1945	27500.0		1992	15100.0	
1946	32900.0		1993	48500.0	
1947	31000.0		1994	28300.0	
1948	60500.0		1995	15600.0	
1949	28400.0		1996	46600.0	
1950	34600.0		1997	31600.0	
1951	36100.0		1998	36400.0	
1952	24700.0		1999	34100.0	
1953	25400.0		2000	38000.0	
1954	29000.0		2001	28900.0	
1955	22500.0		2002	23700.0	
1956	39200.0		2003	33500.0	
1957	21400.0		2004	54700.0	
1958	38300.0		2005	49400.0	
1959	32300.0		2006	76800.0	

Explanation of peak discharge qualification codes

PEAKFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

```
        -  Minus-flagged discharge -- Not used in computation
              -8888.0 -- No discharge value given
        -  Minus-flagged water year -- Historic peak used in computation
Program PeakFq           U. S. GEOLOGICAL SURVEY            Seq.001.004
Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date / Time
05/06/2005          following Bulletin 17-B Guidelines       06/28/2007 16:47

            Station - 01503000  SUSQUEHANNA RIVER AT CONKLIN NY

 EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS
```

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
2006	76800.0	0.0105	0.0105
1936	61600.0	0.0211	0.0211
1948	60500.0	0.0316	0.0316
2004	54700.0	0.0421	0.0421
1913	52000.0	0.0526	0.0526
1940	51800.0	0.0632	0.0632
1964	50200.0	0.0737	0.0737
2005	49400.0	0.0842	0.0842
1943	48600.0	0.0947	0.0947
1993	48500.0	0.1053	0.1053
1914	47000.0	0.1158	0.1158
1929	47000.0	0.1263	0.1263
1996	46600.0	0.1368	0.1368
1979	45200.0	0.1474	0.1474
1925	44900.0	0.1579	0.1579
1984	44700.0	0.1684	0.1684
1986	44400.0	0.1789	0.1789
1924	44000.0	0.1895	0.1895
1960	44000.0	0.2000	0.2000
1928	43500.0	0.2105	0.2105
1977	43400.0	0.2211	0.2211
1916	42100.0	0.2316	0.2316
1935	41900.0	0.2421	0.2421
1915	40500.0	0.2526	0.2526
1978	40300.0	0.2632	0.2632
1922	39900.0	0.2737	0.2737
1956	39200.0	0.2842	0.2842
1961	39100.0	0.2947	0.2947
1958	38300.0	0.3053	0.3053
2000	38000.0	0.3158	0.3158
1963	37800.0	0.3263	0.3263
1998	36400.0	0.3368	0.3368
1951	36100.0	0.3474	0.3474
1962	35300.0	0.3579	0.3579
1920	35200.0	0.3684	0.3684
1950	34600.0	0.3789	0.3789
1938	34100.0	0.3895	0.3895
1999	34100.0	0.4000	0.4000
1927	33600.0	0.4105	0.4105
2003	33500.0	0.4211	0.4211
1939	33100.0	0.4316	0.4316
1946	32900.0	0.4421	0.4421
1959	32300.0	0.4526	0.4526
1973	32100.0	0.4632	0.4632
1976	31700.0	0.4737	0.4737
1997	31600.0	0.4842	0.4842
1947	31000.0	0.4947	0.4947
1975	30700.0	0.5053	0.5053
1926	30600.0	0.5158	0.5158
1944	30000.0	0.5263	0.5263
1983	29800.0	0.5368	0.5368
1918	29400.0	0.5474	0.5474
1932	29000.0	0.5579	0.5579
1954	29000.0	0.5684	0.5684
2001	28900.0	0.5789	0.5789
1917	28700.0	0.5895	0.5895

1949	28400.0	0.6000	0.6000
1994	28300.0	0.6105	0.6105
1942	28100.0	0.6211	0.6211
1945	27500.0	0.6316	0.6316
1923	27300.0	0.6421	0.6421
1921	27100.0	0.6526	0.6526
1972	26500.0	0.6632	0.6632
1934	25400.0	0.6737	0.6737
1953	25400.0	0.6842	0.6842
1980	25400.0	0.6947	0.6947
1970	25300.0	0.7053	0.7053
1987	25100.0	0.7158	0.7158
1933	25000.0	0.7263	0.7263
1989	25000.0	0.7368	0.7368
1941	24900.0	0.7474	0.7474
1974	24900.0	0.7579	0.7579
1952	24700.0	0.7684	0.7684
1981	24700.0	0.7789	0.7789
1937	24300.0	0.7895	0.7895
1969	24000.0	0.8000	0.8000
1991	24000.0	0.8105	0.8105
2002	23700.0	0.8211	0.8211
1931	22800.0	0.8316	0.8316
1955	22500.0	0.8421	0.8421
1971	21700.0	0.8526	0.8526
1988	21500.0	0.8632	0.8632
1957	21400.0	0.8737	0.8737
1968	21200.0	0.8842	0.8842
1990	20300.0	0.8947	0.8947
1985	20000.0	0.9053	0.9053
1930	18600.0	0.9158	0.9158
1966	18000.0	0.9263	0.9263
1919	17900.0	0.9368	0.9368
1982	17700.0	0.9474	0.9474
1967	16800.0	0.9579	0.9579
1995	15600.0	0.9684	0.9684
1992	15100.0	0.9789	0.9789
1965	14900.0	0.9895	0.9895

End PEAKFQ analysis.

Stations processed : 1
Number of errors : 0
Stations skipped : 0
Station years : 94

Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4, or *.)
(2, 4, and * records are ignored.)

For the station below, the following records were ignored:

FINISHED PROCESSING STATION: 01503000 USGS SUSQUEHANNA RIVER AT CONKLIN

For the station below, the following records were ignored:

FINISHED PROCESSING STATION:

```
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.001
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date /
Time
  05/06/2005          following Bulletin 17-B Guidelines       07/09/2007
13:23

             Station - 01502731  SUSQUEHANNA RIVER AT WINDSOR NY


                    I N P U T   D A T A   S U M M A R Y

               Number of peaks in record            =       19
               Peaks not used in analysis           =        0
               Systematic peaks in analysis         =       19
               Historic peaks in analysis           =        0
               Years of historic record             =        0
               Generalized skew                     =   -0.009
                    Standard error                  =    0.321
                    Mean Square error               =    0.103
               Skew option                          =   WEIGHTED
               Gage base discharge                  =      0.0
               User supplied high outlier threshold =   --
               User supplied low outlier criterion  =   --
               Plotting position parameter          =     0.00



  *********  NOTICE  --  Preliminary machine computations.        *********
  *********  User responsible for assessment and interpretation.  *********
    WCF134I-NO SYSTEMATIC PEAKS WERE BELOW GAGE BASE.                    0.0
    WCF195I-NO LOW OUTLIERS WERE DETECTED BELOW CRITERION.           10392.6
    WCF163I-NO HIGH OUTLIERS OR HISTORIC PEAKS EXCEEDED HHBASE.      63428.9
1
```


```
  Program PeakFq           U. S. GEOLOGICAL SURVEY             Seq.001.002
  Ver. 5.0 Beta 8     Annual peak flow frequency analysis      Run Date /
Time
  05/06/2005          following Bulletin 17-B Guidelines       07/09/2007
13:23

             Station - 01502731  SUSQUEHANNA RIVER AT WINDSOR NY
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          ANNUAL FREQUENCY CURVE PARAMETERS -- LOG-PEARSON TYPE III

                        FLOOD BASE                    LOGARITHMIC
                  ----------------------  -------------------------------
```

	DISCHARGE	EXCEEDANCE PROBABILITY	MEAN	STANDARD DEVIATION	SKEW
SYSTEMATIC RECORD	0.0	1.0000	4.4095	0.1664	-0.081
BULL.17B ESTIMATE	0.0	1.0000	4.4095	0.1664	-0.029

ANNUAL FREQUENCY CURVE -- DISCHARGES AT SELECTED EXCEEDANCE PROBABILITIES

ANNUAL EXCEEDANCE PROBABILITY	BULL.17B ESTIMATE	SYSTEMATIC RECORD	'EXPECTED PROBABILITY' ESTIMATE	95-PCT CONFIDENCE LIMITS FOR BULL. 17B ESTIMATES LOWER	UPPER
0.9950	9471.0	9295.0	8162.0	6268.0	12170.0
0.9900	10450.0	10290.0	9311.0	7148.0	13190.0
0.9500	13630.0	13550.0	12930.0	10180.0	16470.0
0.9000	15700.0	15660.0	15200.0	12230.0	18600.0
0.8000	18610.0	18630.0	18310.0	15170.0	21660.0
0.6667	21800.0	21860.0	21650.0	18370.0	25200.0
0.5000	25720.0	25810.0	25720.0	22140.0	29900.0
0.4292	27540.0	27630.0	27610.0	23800.0	32240.0
0.2000	35460.0	35490.0	36040.0	30460.0	43510.0
0.1000	41900.0	41800.0	43240.0	35380.0	53730.0
0.0400	50010.0	49660.0	52980.0	41190.0	67680.0
0.0200	56050.0	55440.0	60820.0	45320.0	78700.0
0.0100	62080.0	61170.0	69260.0	49320.0	90200.0
0.0050	68150.0	66880.0	78460.0	53240.0	102200.0
0.0020	76280.0	74460.0	92040.0	58370.0	119000.0

1

Program PeakFq   U. S. GEOLOGICAL SURVEY   Seq.001.003
Ver. 5.0 Beta 8   Annual peak flow frequency analysis   Run Date / Time
05/06/2005   following Bulletin 17-B Guidelines   07/09/2007 13:23

Station - 01502731 SUSQUEHANNA RIVER AT WINDSOR NY

I N P U T   D A T A   L I S T I N G

WATER YEAR	DISCHARGE	CODES	WATER YEAR	DISCHARGE	CODES
1988	16700.0		1998	34600.0	
1989	19900.0		1999	29700.0	

1990	19700.0	2000	32900.0
1991	18100.0	2001	28100.0
1992	12900.0	2002	20100.0
1993	37200.0	2003	30000.0
1994	24100.0	2004	26400.0
1995	13500.0	2005	35200.0
1996	40000.0	2006	55900.0
1997	27400.0		

Explanation of peak discharge qualification codes

PEAKFQ CODE	NWIS CODE	DEFINITION
D	3	Dam failure, non-recurrent flow anomaly
G	8	Discharge greater than stated value
X	3+8	Both of the above
L	4	Discharge less than stated value
K	6 OR C	Known effect of regulation or urbanization
H	7	Historic peak

- Minus-flagged discharge -- Not used in computation
  -8888.0 -- No discharge value given
- Minus-flagged water year -- Historic peak used in computation

1

Program PeakFq U. S. GEOLOGICAL SURVEY Seq.001.004
Ver. 5.0 Beta 8 Annual peak flow frequency analysis Run Date / Time
05/06/2005 following Bulletin 17-B Guidelines 07/09/2007 13:23

Station - 01502731 SUSQUEHANNA RIVER AT WINDSOR NY

EMPIRICAL FREQUENCY CURVES -- WEIBULL PLOTTING POSITIONS

WATER YEAR	RANKED DISCHARGE	SYSTEMATIC RECORD	BULL.17B ESTIMATE
2006	55900.0	0.0500	0.0500
1996	40000.0	0.1000	0.1000
1993	37200.0	0.1500	0.1500
2005	35200.0	0.2000	0.2000
1998	34600.0	0.2500	0.2500
2000	32900.0	0.3000	0.3000
2003	30000.0	0.3500	0.3500

1999	29700.0	0.4000	0.4000
2001	28100.0	0.4500	0.4500
1997	27400.0	0.5000	0.5000
2004	26400.0	0.5500	0.5500
1994	24100.0	0.6000	0.6000
2002	20100.0	0.6500	0.6500
1989	19900.0	0.7000	0.7000
1990	19700.0	0.7500	0.7500
1991	18100.0	0.8000	0.8000
1988	16700.0	0.8500	0.8500
1995	13500.0	0.9000	0.9000
1992	12900.0	0.9500	0.9500

1

```
 End PEAKFQ analysis.
   Stations processed :       1
   Number of errors   :       0
   Stations skipped   :       0
   Station years      :      19
```

Data records may have been ignored for the stations listed below.
(Card type must be Y, Z, N, H, I, 2, 3, 4, or *.)
(2, 4, and * records are ignored.)

For the station below, the following records were ignored:

FINISHED PROCESSING STATION: 01502731   USGS SUSQUEHANNA RIVER AT WINDSOR

For the station below, the following records were ignored:

FINISHED PROCESSING STATION: